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Office of Naval Research
European Office

89-02

AD-A206 182

ESN INFORMATION BULLETIN

European Science Notes Information Bulletin
Reports on Current
European/Middle Eastern Science

Focus on Materials Science, a Dedicated Issue:

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b DECLASSIFICATION / DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) 89-02	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Office of Naval Research European Office — 6b OFFICE SYMBOL (If applicable) ONREUR	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code) Box 39 FPO, NY 09510-0700	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING / SPONSORING ORGANIZATION — 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
European Science Notes Information Bulletin – (UNCLASSIFIED)

12 PERSONAL AUTHOR(S)
C.J. Fox, Editor

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Multidiscipline	FROM ______ TO ______	February 1989	82

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The European Science Notes Information Bulletin (ESNIB) is a compilation of reports on recent developments in European science of specific interest to the US R&D community, and is issued in support of the mission of the Office of Naval Research European Office. It is not intended to be part of the scientific literature. The value of the Bulletin to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. ESNIB authors are primarily ONREUR staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the US Army Research, Development and Standardization Group. US scientists travelling in Europe may also be invited to submit reports.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	UNCLASSIFIED

22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
C.J. Fox	(44-1) 409-4340	310

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

☆ U.S. Government Printing Office: 1986—607-044

ESN INFORMATION BULLETIN

89-02

This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large.

Commanding Officer ...... CAPT Terry J. McCloskey, USN
Scientific Director .... James E. Andrews
Editor .... C.J. Fox

SOURCE NOTES TO MATERIALS ACTIVITIES IN EUROPE

by LOUIS CARTZ

This eight-part presentation of "source notes" gathered by Dr. Cartz during his tour at ONREUR represents a multitude of informed observations and evaluations resulting from numerous site visits, discussions in depth with a great many experts in their fields, and participatory attendance at many national and international meetings. Appendices A and B have been added as supplementary information published by or available to ONREUR.

CERAMICS RESEARCH IN WEST GERMANY—THE US EMBASSY PERSPECTIVE

This two-part survey of ceramics research in West Germany was originated by the Office of the Science Counselor at the US Embassy in Bonn. Institutional relationships, distribution of funding burdens, directions and emphasis of the research, and specific research tracks are discussed.

NEWS, NOTES, AND ABSTRACTS

About This Issue of ESNIB:

Although not a departure from a precedent already established, this issue is unique in that it features only one discipline and, in addition, that the primary "report" is (in the name given by its author, Dr. Louis Cartz) a set of *Source Notes* – source notes to materials science resources in Europe and the Middle East. As such, we expect that it will have great and continuing utility to the materials community in the United States.

Since the art of materials science has more and more deeply probed into the fundamental behavior of matter, it has involved not only the materials specialists, but also specialists in physics, electronics, chemistry, et al. – theoreticians and experimentalists alike.

In these Source Notes the specialist will find, on the one hand, evidence for realistic evaluation of the state and directions of European materials research and technology and, on the other, the extraordinarily helpful details of institutions and names, addresses, and phone numbers of colleagues who, by the comments given, are shown to be working in areas of primary interest to him.

As for those readers not so directly concerned with materials science, the two-part survey by US Embassy personnel of West German materials R&D can be revealing reading. Implicit in it is a direct view into science policy in the Federal Republic of Germany; the relationships of the academic, industrial, and institute sectors; the dollar value of the R&D investments; and the areas of government and industry emphases. Such information, we believe, will be of interest to a very wide spectrum of readers: What can be extrapolated from the Embassy-supplied information is a picture of already existing – and growing – German determination (and, by extension, European Community determination) to play in the same games – as equals – with the US and Japan. This, from our perspective as full-time observers of European science, applies across nearly all the sciences.

So, welcome to this unique issue. We look forward to devoting future issues to equivalent deep and broad views of other sciences.

SOURCE NOTES TO MATERIALS RESEARCH ACTIVITIES IN EUROPE

by Louis Cartz. Dr. Cartz was the Liaison Scientist for Materials Science in Europe and the Middle East for the Office of Naval Research European Office. He returned to Marquette University, College of Engineering, Milwaukee, Wisconsin, where he is a Professor of Materials Science.

1. Overview

This report is primarily a compilation of information about and descriptions of selected materials research activities (laboratories, organizations, individuals, research programs, and related matters). It is not intended as an assessment of European work in materials science – not even in advanced engineering materials – but rather as an abbreviated guide to who in Europe is doing what (and where) that has potential use or is of other consequence to American workers in the field of materials science. As such, the report represents a set of **Source Notes** to activities in materials research in Europe, but the reader should bear in mind that the coverage has been greatly limited by the time available and also by my own special interests, which led me during my tour in London to pursue particular areas in the field of materials.

The main emphasis is on advanced engineering materials, particularly those for use at very high temperatures under severe conditions. It is this subject which is dealt with in Advanced Engineering Materials (beginning page 3). However, many other studies are closely related to those on these materials. The related topics cover a wide variety of subjects, ranging from corrosion to microscopy, methods of testing, crystal orientation studies, etc. These related subjects are covered under Sections 5, 6, and 7 (beginning page 31). This second group of Sections is therefore, by its very nature, very diffuse, covering a wide range of subjects.

In several cases, workshops and conferences were organized by ONREUR on materials science subjects. Summaries of two of these meetings have been included. Also, for reference across a broad spectrum of materials science as reported by ONREUR, these Source Notes include a list (with brief abstracts where appropriate) of the articles and reports published by ONREUR since 1985. This list is found in Section 9, page 43.

A directory of scientists, laboratories, and organizations concerned with materials studies is given in the Directory of Materials Laboratories (page 5). This directory is, once again, an abbreviated compilation of active centers, influenced very much by subjective considerations and dependent on the relatively short time available to attempt such a compilation of evaluated research centers. The many omissions are from lack of information available to me, not by any careful selective process. The comments in the listings are highly variable – detailed and based on intensive personal evaluations and knowledge in some cases, much less precise data in others. I was not able to visit all of the persons and laboratories; many are listed because of their excellent reputation within the materials community in Europe. Those not specifically visited recently are labelled as "not visited recently" (nvr). I hope this listing will be useful in providing at least a starting point in each country where one can enquire about a particular activity in materials science.

Section 5, titled "Some Exceptional Laboratories of Relevance to Materials Science," includes a list of some particularly useful laboratory facilities; this list is inevitably incomplete, being highly subjective and dependent on my chance of visiting some of the many facilities across Europe. My intention here is to identify those laboratories where important developments can be anticipated. If my itineraries had permitted, this list would undoubtedly be much longer.

It is of use to research workers to be aware of the scientific meetings and organizations active in materials science and related fields. For this reason, I have included a short list (Section 6, page 35) which includes details of two new societies dealing with materials: the new European Ceramic Society, and the new European Society of Materials. It is hoped that these European organizations may simplify the identification and notification to all concerned of scientific meetings in Europe which at present are covered by at least 50 different uncoordinated organizations across Europe. A network of European research programs in all fields – including materials science – is also beginning to evolve, many sponsored by the CEC. A partial list of these is given under "European Societies and Materials Programs" (page 35).

Details of materials conferences to be held in Europe during 1989-90 begin on page 41, and, as stated above, a list of all previously published ONREUR ESN articles and reports (from January 1985 onwards) starts on page 43. This review does not adequately cover polymer sciences, or metallurgical studies, except by occasional reference to studies closely related to ceramic studies. Nevertheless, several metallurgical and chemical societies and organizations in Europe are listed in the materials directory, Section 3, page 5.

Further Work on Evaluations and Reviews

Various fields and areas of study deserve greater coverage than was possible for this report. The following subjects are those where important developments are in progress, and where it would be useful to undertake a more detailed review.

Composites. The various articles and reviews on composites presented recently in *ESNIB* are discussed in Section 2. However, they do not fully cover the extent of developments and research studies in progress. Much work is known to be in progress on preparing new fibers, whiskers, and other special particulate forms (ceramic, metallic, polymeric, glassy, graphitic). Very important advances are being made in the various research groups working closely together in France, particularly in the Bordeaux area (SEP, Aerospatial, IMC, University of Talence; also ONERA, Ecole des Mines de Paris, and the University of Limoges). Other studies are being undertaken in the UK at Bath and Harwell, or sponsored by British Petroleum and ICI, and still other studies are in progress at various universities in Sweden, Greece , and Germany.

While some description of these studies is given, it would be worthwhile to concentrate very deliberately on reviewing ongoing studies in the field of composite materials, both ceramic-ceramic in nature as well as the ceramic-metallic, ceramic-polymer, and other types. This is a fast-evolving field with significant future importance.

Materials Characterization. There are very many methods of examining materials to characterize their properties. These range from nondestructive testing (NDT) methods (neutron, x- and γ-radiography, ultrasonics, thermography, etc.) through to the most sophisticated electron optical studies. Some limited discussions have been presented on neutron-radiography, positron annihilation, advanced electron optics, and surface analysis methods, and some references are given to acoustic emission (AE), surface tribology, and hardness testing, among others. In particular, there is considerable difficulty in carrying out tests on materials at temperatures above 1400°C, and the testing of properties such as hardness, toughness, friction, and many others are not simple to carry out. Obviously, further work needs to be done to extend our capabilities.

Metal-Ceramic Bonding: Heterogeneous Interfaces. This is a very important industrial topic. At present, there is the impression that some interesting advances are being made, or that the stage is being set for important advances to occur. There are, for example, the studies of heterogeneous solid-solid interfaces at Stuttgart ([item] 107, page 16) and at Oxford (23, page 8) (see *ESN* 88-01:41 [1988]). There are other interesting aspects to this topic – the behavior, for example, of the interface between fiber and matrix in composites (see *ESN* 41-10:555[1987]). In any case, a careful review of studies of heterogeneous solid-solid interfaces should be undertaken.

Microscopy. Several very interesting developments in microscopy have occurred in the fields of scanning tunnelling (STM), atomic force (AF), atom probe, optical, and acoustic as well as in other scanning analytical systems (SEM, SAM). Many laboratories are deeply involved. Any relevant list would include Oxford University (23, page 8); IBM Zurich (129, page 18); Chalmers University (99, page 15); Warwick University (22, page 8); University of Pau, France (91, page 14); MPI Stuttgart (107, page 16); University of Surrey (40, page 10); and the University of Cambridge (17, page 8).

Work in "Other" European Countries. Advanced scientific endeavor is generally considered to be concentrated for the most part in well-known centers of northern Europe. These are in the UK, France, West Germany, the low-countries, Scandinavia, Switzerland, Austria, and Northern Italy. Nevertheless, several research laboratories in universities and research institutes elsewhere in Europe are making excellent progress. As an example, there is the fine work on chemical engineering processes, lasers, solid-state physics and memory materials at Patras and Hieraklion, Greece, and solid-state physics and ceramics at Madrid, Spain (see *ESN* 88-04:21-23 [1988] and Science Newsbrief 6-5 [1988]).

At many conferences in Western Europe, there are participants from Eastern Europe, particularly from Hungary, Poland, East Germany, and the USSR. Very often, their reputations as well as their scientific contributions are of a high standard.

Many of the Eastern European laboratories are not well known and tend to be overlooked. A careful review of the work of such laboratories would be most useful, along with many of those located around the Mediterranean area in Spain, Italy, Greece, and Turkey.

In the Directory of Materials Laboratories, Section 3, a very brief list is given of Eastern European laboratories and scientists who have a high reputation in materials science studies.

2. Advanced Engineering Materials

These Source Notes are heavily slanted towards ceramic materials, particularly those of use at high temperatures. Indeed, the materials considered in this report are really defined by the contents of this section: nitrogen ceramics, ceramic-ceramic composite materials, surface treatments including surface hardening processes, toughened ceramics, and glass-ceramics. A wide range of other materials are also considered.

The method of presenting the data is not the same in each case, nor does the term "review" apply uniformly to the different topics discussed. In general, the data is presented in the form of source notes, so that it should be possible, at least, to locate or identify a starting point in any reading or investigation of studies in Europe. Some reviews are presented, though often these take the form of abstracts and recommendations from the workshops and conferences sponsored in the main by ONREUR. As an example, nitride ceramics are reviewed in the "summary-recommendations" of the ONREUR Workshop on Engineering Materials at Very High-Temperatures (held in 1987 in the UK. Similarly, the abstract-recommendations are given for Ceramic Toughening Mechanisms in Section 4.

Some topics are presented by referring to the main European centers of work, relevant ONREUR publications (*ESN, ESNIB, Science Newsbrief*), and source notes of active centers of studies in progress along with information of European organizations dealing with conferences, cooperative research programs, and projects.

Nitride Ceramics

The nitride ceramics are being and have been investigated in a very large number of industrial, government, and university laboratories across Europe.

The main laboratories concerned with research on and development of nitride ceramics in Europe include the following:

- University of Newcastle, UK (D. P. Thompson) (see ESN:87-0:23 and ESN:87:41-11:632); 21, page 8.
- Université de Limoges, France (M. Billy and M. Goursat) (see ONREUR Report 1988-88-004-C); 65, page 12.
- Max-Planck Institute, Stuttgart, West Germany (Dr. Petzow), 107, page 16.

The original development of these materials is closely associated with K. Jack, now retired from the University of Newcastle-upon-Tyne, and that work was sponsored and aided by the UK's Lucas-Cookson-Syalon Ltd (LCS) (19, page 8). The commercial exploitation of the N-ceramics is being undertaken by this organization, LCS, with many N-ceramics under license to Sandvik Hard Materials, Sweden, and other European and US firms. Development work is proceeding at LCS, some in association with D.P. Thompson (University of Newcastle).

Recent work on N-ceramics is reviewed in the abstract and recommendation of the ONREUR workshop, in Section 4. This workshop on "Engineering Materials for Very High Temperature" considered N-ceramics, and also other materials such as the ceramic-ceramic composites, carbides, and borides, as well as coatings on metal surfaces; see *ONREUR Report* 8-016-R.

Ceramic-Ceramic Composite Materials

A very fruitful range of research studies and technological developments on composite materials have been carried out in Europe, and particularly in France over the past 10-20 years. Many organizations have been involved, with many scientists working closely together, resulting in the establishment of some important and useful materials which are being commercially exploited.

The main ceramic-ceramic composite systems under development are:

- C-C composites (with one-, two-, or three-dimensional weave)
- SiC-SiC
- Si nitride with ceramic whiskers
- SiC with ceramic whiskers
- SiC undirectional fibers + SiO_2 matrix
- SiC fiber + refractory silicate glass ceramics.

The organizations and laboratories in France working on ceramics-ceramic composite materials are:

1. Société Aérospatiale, Laboratoire Matériaux Composites (70, page 12); scientists: A. Hordonneau, Y. Grenie. (Three-dimensional C-C composites, massive structures. SiC composites.)
2. Société Européenne de Propulsion (SEP); (69, page 12); scientists: M. Heraud, M. Lamicq. SiC-SiC whisker-reinforced, oxidation-protection studies.
3. Institut des Matériaux Composites (IMC) (71, page 12); Director R. Naslain: general aid to industrial research in all aspects of all composite types, including polymer-glass and ceramic-ceramic.
4. Office National d'Etudes et de Recherches Aerospatiales (ONERA) (67, page 12); Scientists: J.F. Jamet, P. Costa (Department Head), Ceramic Composites. Interfacial fiber matrix studies.
5. Ecole Nationale Supérieure des Mines de Paris; Centre des Matériaux; (78, page 13); scientists: D. Brous-

saud, J.P. Trottier (Director), A.R. Bunsell (mechanical and thermal testing of ceramic composites and C fibers.

6. Association pour les Matériaux Composites (AMAC) (59, page 11)

All of the French organizations work very closely together, and the successful development of composite materials in France has resulted from this close association of scientists and industrialists. The organization AMAC plays an important role in this, holding regular meetings on all aspects of composites, where workers from industrial, government, and university laboratories can meet freely (the proceedings are always in French). (References: 45 and 46, page 41.)

The following organizations, numbers 7-10, are working in the UK on composite computer science and technology.

7. Harwell (24, page 8). See *ESN* 41-10:590(1987). SiC fiber weaves in pyrex glassy matrices.

8. University of Bath (38, page 10), Professor B. Harris; acoustic emission (AE) testing, cellular composite materials, natural fibers and polyester resins, impact damage tolerance, C-C composites failure characteristics.

9. Fulmer Research Institute; design of polymer matrix-glass fiber components (e.g., helicopter blade components; seagoing, nonmagnetic vessels [11, page 7]).

10. University of Manchester, Institute of Science and Technology (UMIST), Professor R.J. Young (39, page 10). Single-crystal polymer fibers in polyurethane matrices.

Some European organizations concerned with composite materials are listed in numbers 11 through 13, below.

11. European Composite Forum, Espace Forum 33, 54, cours du Chapeau-Rouge, 33000 Bordeaux, France. Directors: Dr. A.R. Bunsell, Dr. A. Massiah. Scientists and industrialists from at least seven European countries are collaborating (UK, France, Sweden Denmark, Germany, Italy, Belgium).

12. European Trade Association of Advanced Composite (ETAC) Suppliers, c/o Fides Treuhangesellschaft, Postfach CH-8027 Zurich, Tel: (01) 249 2121, Telex: 815 407. Secretary, P.W. Meier

13. Dr. A. Roulin-Moloney, EPFL, Lausanne, Switzerland (128, page 18). Polymer-fiber-reinforced matrices. See *ESN* 88-04:26, "Materials Research Lausanne, Switzerland."

Composite materials for use at high temperatures were considered at the ONREUR workshop on "Engineering Materials at Very High Temperatures" (proceedings in ONREUR Report 8-016-R); summary comments are given on pages 22 and 23; see also *ONREUR Report* (1987) 7-020-R, "Ceramic-Ceramic Composites Meeting in Belgium."

Surface Properties of Materials

There are various important developments in the treatment of surfaces, and some source notes concerning these are briefly listed here.

- Ion beam modification: J.C. Dran, Orsay, France, (82, page 13), G. Carter, Salford, UK, (18, page 8), J. Grilhé, Poitiers, France, (66, page 12)
- Laser beam modification of materials: W. Kurz, EPFL, Lausanne (Laser Beam Treatment of Surfaces, page 31)
- Plasma Coatings: P. Fauchais, Limoges, France, (Thermal Plasma Technology, page 32)
- Dynamic Ion Beam Mixing: M. De La Fon, Poitiers, France (66, page 12)
- Surface Analysis Methods: J.F. Watts, Surrey, UK, (Surface Analysis Laboratory, page 32) VG Scientific, (Ultra-High Vacuum Systems, page 34).

A particularly interesting study on antiwear surface hardening by ion implantation has been carried out by several laboratories in France working closely together. Ion implantation of N in steels, and in other materials, results in hardening effect which persists over greater depths than expected. D. Treheux, (Ecole Centrale de Lyons, France) (87, page 14) has explained this effect as due to fine crystals of Fe-nitrides pushed down into the body of the material during wear. Ion implantation studies are being carried out to improve surface heardness and wear resistance, at the following laboratories that work and collaborate together.

- Laboratoire de Métallurgie, Ecole Centrale de Lyon, (D. Treheux); 87, page 14.
- Unirec, Centre de Recherches d'Unieux; (D. Fayeulle, R. Levegue, C. Chabrol); 76, page 13.
- Institut de Physique Nucléaire de Lyon (IPN), (N. Moncoffre); 92, page 14.

The experimental systems available are:

- Isotope separator, ion fluence 1018 ions cm^{-2}, current density 20 Acm^{-2}, 100 keV
- Grazing incidence x-ray diffraction GIXD
- Tribometry (cylinder flat-pin)
- Nitrogen profile: $^{15}N(p,\alpha\delta)^{12}C$ nuclear resonance reaction, spatial resolution 5nm perpendicular to surface [p from 2.5 MV Van de Graaf]
- Conversion electron Mossbauer spectroscopy (CEMS), secondary ion mass spectroscopy (SIMS).

References: 25, 26, and 27, page 40.

A European conference, sponsored by ONRL, was held in Ankara, Turkey (May 1988) on "Surface Science and Technology." The review and recommendation for that conference will be available at a future date.

Ceramic Toughening Mechanisms

There are several mechanisms which can toughen ceramics and these are described. A workshop sponsored by ONREUR was held in Stuttgart (April 1988); the review and recommendations from that conference are given in Appendix III at the end of Part I. [Whisker/fiber reinforcement is discussed under Ceramic-Ceramic Composite Materials, page 3.]

Two toughening mechanisms are noted here:

- Metastable phase transitions. Work on the ZrO_2 (Tetragonal-Monolinic) metastable transition is discussed in *ESN* 41-11:632-635[1987] and *ESNIB* 87-01, 29-32. The scientists involved include R. Stevens (Leeds, UK) and M. Lewis (Warwick, UK); 16, page 7 and 22, page 8.
- Reaction Sintering (Al_2O_3-TiN). This is discussed in *ESNIB* 88-04:26. The scientist concerned is A. Mocellin (Ecole Polytechnique Fédérale de Lausanne); 128, page 18.

Glass Ceramics

Very interesting work is in progress at the University of Warwick (UK) (22, page 8) by M. Lewis and D. Holland on glass ceramics, as well as electroceramics and optical ceramics. Research has centered on the structure of nonsilicate glasses and of crystalline solids, and the development of glass ceramics for high-temperature applications. These studies are funded by about 20 of the largest British industrial groups.

The laboratory facilities at Warwick include:

- Magic-Angle Spinning Nuclear Magnetic Resonance (MAS-NMR)
- Compton-scattering spectroscopy
- Secondary ion mass spectrometry (SIMS), transmission electron microscopy (TEM) (200 keV).

The range of glass-ceramics studies is given below; most of them are carried out in cooperation with UK industries.

- Glass ceramic thermal barrier coatings
- Glass ceramics for very large scale integrated circuitry (VLSI) packaging and substrates
- Oxynitride glass-ceramics, and nitride ceramics for gas-turbines
- Whisker-toughened glass-ceramic composites
- MAS-NMR structural studies of glasses and ceramic phases
- Compton-scattering spectroscopy in nondestructive evaluation (NDE) of materials
- Glasses for infrared optical fibers

Reference: 28, page 40.

3. Directory of European and Middle Eastern Materials Laboratories

The following directory of laboratories, individuals, and government offices in the field of materials science and related topics is certainly not complete. Those listed, and the notes or comments I have been able to provide are a direct result of my opportunities for on-site visits or other forms of contact during the recent past. The brevity or detail of comment in each case also reflects the same opportunities. Many active – and excellent – centers are no doubt missing from this list, not because they were left out in a selection process, but simply because no information was available to me about them. In any case, my prime objective here has been to provide the names and addresses of people and institutions that can serve as starting points in any inquiry.

The list is arranged by country, and where applicable, under each country by:

- Government agencies and programs
- Scientific societies
- Research laboratories and scientists.

The listing is inevitably incomplete, and can in no way, be considered to give a balanced view of the nature of scientific work being carried out in the different parts of Europe. Where the activity listed has not been visited recently, it is marked by "nvr" (not visited recently).

The countries considered (and the page numbers their entries begin on) are:

United Kingdom (UK)

1. Department of Trade and Industry (DTI)
Chemistry, Textiles, Paper & Miscellaneous (CTPS) Division
Ashdown House
123 Victoria Street
London NW1E 6RB
UK
Telephone: 01-212-0261

Materials are the responsibility of Mr. David C. Milner. Mr. Tom J. Sinclair is the person responsible for nonmetallic materials. He is directly concerned with two programs, Ceramic Applications in Reciprocating Engines (CARE) and Advanced Ceramic Turbines (ACT).

2. Advanced Ceramics Turbines (ACT), UK
UK Ceramics Club, (Gas Turbines)
Committee Chairman, Mr. G.W. Meetham
Rolls-Royce plc (see item 13, page 7)

Rolls Royce plc (RR) initiated meetings with industrial, university, and research institutes several years ago. From these meetings, two programs, aided by DTI (CTPS), have developed: ACT in 1984, and CARE in 1986. ACT is concerned with high-temperature ceramics, processing, and composites for gas turbines. RR is taking the lead in this program. There are about 12 projects funded at around $4 million for 3 years. DTI funds 50 percent of the program. CARE is a program concerned with diesel engines. It is a 4-year program with a budget of $10 million, and there will be 12 projects. About the same time as the RR initiative, the NIMP Collyear Report (see reference 13, page 40) was published and their recommendations have been accepted by the UK government, though only partially implemented.

3. Materials Committee
Science and Engineering Research Council (SERC)
Polaris House
North Star Avenue
Swindon SN2 1ET
UK
Telephone: 0793 26222

The SERC is responsible for funding for research at UK universities. During 1984-1985, 132 grants of total value about $10 million were funded.

4. Daresbury Laboratory (SERC)
Warrington, WA4 4AD
UK
Director L.L. Green

This laboratory is run by SERC with special facilities of the Nuclear Structure Facility (van de Graaff 29 MV ions; protons to Bi) and the Synchrotron Radiation Source (2 GeV electron storage ring).

Scientific Programs at the Daresbury Laboratory cover:

- *Surfaces and Solid*
- *Biological Sciences*
- *Materials Science (atomic and electronic structure) using small-angle x-ray scattering, x-ray topography, x-ray spectroscopy, x-ray fluorescence, and glancing-angle extended x-ray absorption fine structure (EXAFS).*

5. British Association for the Advancement of Science (BAAS)
B.A.A.S. Sections
Fortress House
23 Savile Row
London W1X 1AB
UK

The BAAS is composed of 15 divisions including physics, chemistry, and engineering.

6. Institute of Ceramics
Shelton House
Stoke Road
Shelton, Stoke-on-Trent ST4 2DR
UK
Telephone: 0782-202116

7. Institute of Physics
47, Belgrave Square
London SW1 8QX
UK
Telephone: 01-235-0016

8. Institute of Metals
1, Carlton House Terrace
London SW1Y 5DB
UK
Telephone: 01-839-4071
Sir Geoffrey Ford (secretary)

9. British Crystallographic Association
Secretary
Dr. Judith A.K. Howard
University of Bristol
School of Chemistry
Cantock's Close
Bristol
UK BS8 1TS

10. Royal Society of Chemistry
9, Savile Row
London W1
UK
Telephone: 01-734-9864

11. Fulmer Research Institute
Holly Bush Hill
Stoke Poges
Slough SL2 4QD
UK
Telephone: 02816-2181
Dr. G.I. Williams
Dr. Grenville Brook

The Fulmer Research Institute (FRI) is a contract-research institute, a wholly owned subsidiary of the UK Institute of Physics. The FRI specializes in studies of:

- *Nondestructive testing (ultrasonic piezoelectric polymer transducers)*
- *Abrasion tests*
- *X-ray diffraction studies (analysis and crystal structures)*
- *Composite materials*
- *Alloy engineering (shape memory, wear and corrosion resistance, superplastic alloy, magnetic alloys, alloy processing)*
- *Automation and robotics – FRI has a very high reputation and works extensively with a wide range of UK and European industries.*

12. British Ceramic Research Ltd
CERAM Reasearch
Penkhull
Stoke on Trent
Staffs ST4 7LQ
UK
Telephone: 0782-45431
Dr. D. Lloyd
Mr. John Cotton
Dr. D.A. Bell

CERAM is the Ceramics Research Institute supported by the British ceramic industry. It covers the whole range of industrial ceramic activities from structural ceramics, whitewares, refractories, advanced ceramics (ZrO_2-based, ceramic components for engines, Si_3N_4-based ceramics), and building materials.

CERAM undertakes studies such as x-ray diffraction crystal structures, tensile creep testing of ceramics, cement materials, fabrication methods, geological services.

13. Rolls-Royce plc (RR)
PO Box 31
Derby DE2 8BJ
UK
Telephone: 0332-242424
G.W. Meetham (Chief, Materials R&D)
Dr. C. Baxter (x-ray diffraction)

RR sponsors, or makes extensive use of research facilities at the universities and elsewhere in the UK. A short list of RR's studies covers:

- *Neutron-radiography of turbine blades*
- *Positron analysis of engine wear*
- *Microcrack propagation in powder metallurgy specimens*
- *Single crystal orientation (turbine blades) (page 35).*

14. Rolls-Royce plc
Advanced Projects Department
PO Box 3, Filton, Bristol
BS12 7QE
UK
Scientist: P. A.E. Stewart

Studies: positron annihilation testing of lubrication effects (page 33).

15. Imperial Chemical Industries (ICI) plc,
Research and Technology Department
PO Box 8 The Heath Runcorn
Cheshire WA7 4QE
UK
Telephone: (0928) 513465

The "New Science Group" of ICI is directed by Professor Birchall. The materials under development include:

- *Macrodefect-free cements (MDF)*
- *High-strength cements*
- *Phosphate binders*
- *Ceramic fibers (SAFFIL Al2O3)*
- *Organic fibers (PEEK, PTFE, PES)*
- *Carbon-fiber-reinforced polymers.*

16. The Department of Ceramics
University of Leeds,
Houldsworth School of Applied Science
Leeds LS2 9JT
UK
Telephone: 0532-431751
Faculty includes:
Dr. Ron Stevens
F.L. Riley
N.W. Thomas

This ceramics department is the largest in the UK. Extensive studies are carried out with industry, often of an applied nature. Topics covered include:

- *Toughening ceramics (ZrO_2 based) (see Ceramic Toughening Mechanisms, page 5)*
- *Electroceramics (perovskite-related structures)*
- *Sintering and microstructure development*
- *Chemical routes for preparing ceramic powders.*

A clean room is being set up for the preparation of high-purity ceramics.

17. University of Cambridge

Studies of materials are carried out at two locations at Cambridge:

Department of Metallurgy and Materials Science of Physics
Pembroke Street
Cambridge CB2 3QZ
UK
Telephone: 0223-334400

Cavendish Laboratory
Department of Physics
Madingley Road
Cambridge University
Cambridge CB3 0HE
UK
Telephone: 0223-337206

The research activities at Cambridge are carried out by very many research workers and cover many topics. These include:

- *Catalysis*
- *Engineering ceramics*
- *Corrosion*
- *Electronic, magnetic, and superconducting materials*
- *Extraction metallurgy, electrometallurgy, and metal conservation*
- *Grain boundary and surface phenomena*
- *Polymers and composites*
- *Rapidly quenched alloys*
- *Thin films and layered structures*
- *Tribology.*

Dr. J.E. King studies microcracks in superalloys formed by powder metallurgy. These studies are in collaboration with Rolls Royce.

18. Department of Electronic Engineering
nvr University of Salford
Salford M5 4WT
UK
Telephone: 061-7365843, ext. 418
Dr. George Carter

Surface Modification of Properties (see ESNIB 88-02:40-44 [1988])

19. Lucas Cookson Syalon Ltd.
nvr Cranmore Boulevard
Shirley, Solihull
West Midlands B90 4LL
UK
Telephone: 021-744-2234
Dr. MacDonald
The Consultant Scientist is Professor K. Jack

Sialons, nitrogen-ceramics, ceramic cutting tools: This organization has sponsored much of the work carried out at the University of Newcastle on sialons. Many of their products are produced under license by Sandvik (Sweden) and many US companies.

20. Dr. Paul Popper
22, Pembroke Drive
Newcastle-Under-Lyme
Staffs ST5 2JN
UK
Telephone: 0782-61-11-56

Dr. Popper, who is retired from the British Ceramics Research Association, is the editor of High Technology Ceramics, *and is well known in the field of high-temperature engineering ceramics (such as Si_3N_4-based and SiC).*

21. Department of Metallurgy and Engineering Materials
University of Newcastle-Upon-Tyne
Newcastle-Upon-Tyne NE1 7RU
UK
Telephone: 091-232-851
Dr. Derek P. Thompson

(see Nitride Ceramics, page 3)

22. Department of Physics
University of Warwick
Coventry CV4 7AL
UK
Telephone: 0203-523392
Dr. M. Lewis and
Dr. D. Holland

(see Glass Ceramics, page 5)

23. Department of Metallurgy and
Science of Materials
University of Oxford
Parks Road
Oxford OX1 3PH
UK
Telephone: 0865-273700
Sir Peter Hirsch, FRS

(see Electron Microscopy, page 34)

24. Materials Division
AERE Harwell
DIDCOT
Oxfordshire OX11 0RA
UK
Telephone: 0235-24141
(See *ESN* 41-10:590-592 [1987])

A group in this division under Dr. R. Davidge is working on SiC-fiber composites (see Ceramic-Ceramic Composite Materials, page 3).

25. National Non-Destructive Testing Centre
Harwell Laboratory
Didcot
Oxfordshire OX11 0RA, UK
UK
Telephone: 0235-24241
(See page 33)

26. Pilkington Brothers plc R&D Laboratories
nvr Hall lane
Lathom
Ormskirk L40 5UF
UK
Telephone: 0695-34362
Mr. B.A. Proctor

27. University of Bristol
nvr Department of Physics H.H. Wills Physics Laboratory
Tyndall Avenue
Bristol BS8 1TL
UK
Telephone: 0272-24161
Dr. K.H.G. Ashbee

28. Department of Materials Engineering
University College
Singleton Park
Swansea
SA2 8PP
UK
Telephone: (0792) 295243
Professor B. Wilshire

This department specializes in studies of creep and the fracture of engineering materials and structures: superalloys, Ti alloys, steels, polymers, ceramics. Very careful measurements of creep are undertaken, which permit the forecasting of creep behavior. Extensive studies are carried out on behalf of industry including Rolls Royce, and other UK industries. Professor Wilshire organizes a well-attended international conference on creep and fracture every 2 to 3 years at Swansea.

29. Rutherford-Appleton Laboratory,
Didcot, Oxford, UK
UK
Telephone: 0235-44-6649
ISIS pulsed neutron source

30. Royal Signal and Radar Establishment
St. Andrews Rd.
Malvern
Worcs. WR14 3PS
UK
Telephone: 06845-2733
Jim Savage
Alan Letlington

This institute has an excellent reputation. Work is in progress on ceramic materials and hard diamond carbon coatings.

31. Cranfield Institute of Technology (CIT)
Cranfield
Bedford MK43 0AL
UK
Telephone: 0234-750111
Dr. Brian Hochenhull (Material Science)
- *Marine technology*
- *Underwater welding*

CIT has a Joint University Program with the University of Technology, Compiègne (near Paris).

32. National Physical Laboratory
Teddington
Middx TW11 0LW
UK
Telephone: 01-943-6024
Dr. F.J. Lockett (Head, Materials Division)
Dr. Ian Sced (Polymers, section head)
Dr. Tom B. Gibbons (High Temperature Materials)
Dr. Peter E. Francis (Corrosion)
Dr. John A. Champion (Ceramics metal matrix composites)

33. BP Research Centre, Chertsey Road
Sunbury-on-Thames, Middx TW16 7LN
UK
Telephone: 0932-762028
Dr. Steven Bold, Manager Structural Materials
Dr. Allen Begg

BP undertakes extensive sponsoring of research studies at UK universities.

Examples of the studies of the Advanced Materials Group are:
- *ZrO_2-based engine parts*
- *Metal matrix composites*
- *Novel coatings of bearings*
- *Monofilament-reinforced Al*
- *Particulate-reinforced Al*
- *Energy absorbing tube*
- *Drill bit materials*
- *Flare-tip materials*
- *Mechanical properties of ice*
- *Metal-composite bonding*
- *Filament winding of pressure vessels.*

This research group is very highly regarded and has an excellent reputation.

34. International Research & Development
nvr Laboratory
Newcastle-upon-Tyne
UK
Telephone: 091-265-0451
Dr. Mike Johnson

This contract research institute has had considerable success working with British industry.

35. Standard Telecommunication Laboratories Ltd.
London Rd., Harlow
Essex CM17 9NA
UK
Telephone: 0279-29531
Professor C.H.L. Goodman

Excellent work undertaken in all aspects of semiconductor devices, and related materials.

36. Morgan Materials Ltd.
nvr Bewdley road
Stourport-on-Severn
Worcestershire DY13 8QR
UK
Telephone: 02993-71544
Managing Director: Dr. D.F. Cooper

Refractories engineering ceramics, and carbon products. This is a very sensible and successful laboratory.

37. Imperial College of Science & Technology
nvr Department of Metallurgy & Materials Science
Prince Consort Road
London SW7 2AZ
UK
Telephone: 01-589-5111
Professor B. Steele

38. University of Bath
School of Materials Science
Claverton Down
Bath BA2 7AY
UK
Professor Bryan Harris

Composite Materials (8, page 4)

39. University of Manchester
Institute of Science and Technologies (UMIST)
Department of Polymer Science and Technology
P.O. Box 88
Manchester, M60 1QO
UK
Professor R.J. Young

Composite Materials (10, page 4)

40. The Surface Analysis Laboratory
Microstructural Studies Unit
University of Surrey
Guildford, Surrey GU2 5XH
UK

This laboratory is under the direction of J.F. Watts and J.E. Castle.

(see Surface Analysis Laboratory, page 32)

41. University of East Anglia, UK
nvr *(see Positron Annihilation Laboratories, page 33)*

42. VG Scientific Ltd.
Imberhorne Lane
East Grinstead
West Sussex, RH19 1UB
UK

(see Ultra-High Vacuum Systems, page 34)

43. Osprey Metals Ltd.
Red Jacket Works
Midland
Neath, Glamorgan
SA11 1NJ
UK

(see Osprey Powder Metallurgy Processing, page 34)

FRANCE

Government Agencies and Programs.

There does not appear to be a central program related to materials research in France. Many government agencies are involved; these are listed below.

44. Association Nationale de la Recherche Technique (ANRT)
Siége Social
101, Avenue Raymond Poincaré
75116 Paris
France
Telephone: (1) 45 01 72 27

45. Agence Nationale de Valorisation de la Recherche (ANVAR)
43 rue Caumartin
75435 Paris Cédex 09
France
Telephone: 42 66 93 10

46. Programme Interdisciplinaire Recherche Matériaux(PIRMAT)
Centre National Recherche Scientifique (CNRS)
quai Anatole France
75005 Paris
France
Telephone: 4-55-92-25
M. Hanus and Mme Percheron

47. Délégation Générale pour l'Armement (DGA)
Direction des Recherches Etudes et Techniques (DRET)
26, Bd. Victor
75015 Paris
France
Telephone: 4-552-49-40
Mme Christine Levy and M. Phillipe Durouchoux

48. Centre d'Etude sur les Science et les Techniques Avances (C.E.S.T.A.)
1, rue Descortes,
75005 Paris
France
Telephone: 46-34-36-09
Mme Anne Marie Sajot and M. Lavean

49. Ministère de la Recherche et de l'Enseignement Supérieur
Telephone: 46-34-35-35
1, rue Descartes
75005 Paris
France
Mme Jacqueline Mirabel

50. Etablissement Technique Central de l'Armement (ETCA)
Telephone: 1-656-52-20
(same address as CTME [No. 53])

51. Centre d'Analyse de Defense (CAD)
Telephone: 1-655-96-00
(same address as CTME [No. 53])

52. Centre Mécanique Chimie Matériaux (CMCM)
Telephone: 1-656-52-20
(same address as CTME [No. 53])

53. Centre de Techniques et Moyens de Mesures et d'Essais (CTME)
Telephone: 1-656-52-20
16 bis, avenue Prieur de la Cote d'Or
94114 Arcueil Cédex
France

54. Centre d'Etudes du Bouchet (CEB)
[sometimes referred to as "Bouchet"]
B.P. 3.9170
Vert-le-Petit
France
Telephone: 16-493-22-61

55. Centre d'Etudes de Gramat (CEG)
[sometimes referred to as "Gramat"]
46500 Gramat
France
Telephone: 65-38-73-70

French Scientific Societies.

56. Société Francaise de Physiques
33, rue Croulebarbe
Paris, 13e
France
Telephone: 707-32-98

57. Groupe Francais de la Céramique (GFC)
23, rue de Cronstadt
75015 Paris
France
Telephone: 1-45-31-18-10
Secretary: M. Henri LeDoussal
President M. Daniel Broussaud
This organization set up by the French scientists themselves. It is very active and their meetings are well attended from all levels of the ceramic industry.

58. Société Francaise de Céramique
23, rue de Cronstadt
75015 Paris
France
Telephone: 1-45-31-18-10

59. Association pour les Matériaux Composites (AMAC)
Centre de Matériaux
60, boulevard Saint Michel
75272 Paris Cedex 06
France

60. Société Chimique de France
250, rue St. Jacques
Paris 5e
France
Telephone: 1-43-25-20-78

61. Société Francaise de Métallurgie
1-5, rue Paul Cezanne,
75008 Paris
France
Telephone: 45-63-17-10
Yves Franchot (General Secretary)

62. Centre d'Etudes des Métaux
158, Cours Fauriel
42023 St. Etienne
France
Telephone: 77-42-01-23
M. Leon Glenat (General Secretary)

63. Société des Ingenieurs et Scientifiques de France (ISF)
19, rue Blanche
75009, Paris
France
Telephone: 874-83-56

64. Association Francaise pour l'Avancement des Sciences
Secretariat:
250, rue Saint-Jacques
Paris (5e)
France
Telephone: 326-93-13

FrenchResearchLaboratories.

65. Université de Limoges
U.E.R. des Sciences
123 Avenue Albert Thomas
87065 Limoges
France
Telephone: 55-45-72-00

(see Nitride Ceramics, page 3, M. Billy and M. Goursat; Thermal Plasma Technology, page 32. P. Fauchais; ONRL Report 8-004-C [1988], "Nitrogen Ceramics Meeting in France"; and ESN 40-10:360-62 [1986])

66. Laboratoire de Métallurgie Physique
Faculté des Sciences
40, Avenue du Recteur Pineau
86022 Poitiers Cédex
France
Telephone: 49-45-18-14
Professor J. Grilhé and M. de la Fon

(see ONRL Report 7-014-R [1987], "Metal Physics, Université de Poitiers, France")

67. Office National d'Etudes et de Recherches Aérospatiale (ONERA)
92, Av de la Division Leclerc
92322 Chatillon Cédex
France
Telephone: 46-57-11-60
Dr. J. Jamet

(see Ceramic-Ceramic Composite Materials, page 3)

68. Ecole Nationale Supérieure de Céramique Industriel (ENSCI)
47 av. Albert Thomas
F 87065 Limoges
France
Telephone: 55-79-34-80
Dr. Baumard and Dr. Philip Boch

This is the main industrial ceramics school in France, with extensive cooperative projects, mainly applied studies, with industry.

69. Société Européene de Propulsion (S.E.P.)
Establissement de Bordeaux
Le Haillan BP37
F33165 St. Médard-en-Jalles
Telephone: 56-34-84-90
M. Heraud, M. Lamicq

(see Ceramic-Ceramic Composite Materials, page 3)

70. Establissement d'Aquitaine, Laboratoire Matériaux Composites
Société Aérospatiale
St. Médard-en-Jalles
B.P. 11, 33165
France
Telephone: 36-57-39-52
M. Hordonneau

(see Ceramic-Ceramic Composite Materials, page 3)

71. Institut des Matériaux Composites
Rue G. Monge
Parc Industrial Bersol
33600 Pessac
France
Telephone: 56-36-94-00

72. Centre de Spectromètrie Nucléaire et de Spectrométrie de Masse
batiments 104-108
B.P. 1 91406 Orsay
France
Telephone: 69-41-67-50
J.C. Dran

This center studies surface modification of properties (see ESN 88-02:40-44 [1988], "NATO Meeting on Ion Beam of Modification Materials"; also see Surface Properties of Materials, page 4)

73. CNRS Laboratory
"Physics of High Temperatures"
1D, Avenue de la Recherche Scientifique
45045 Orleans Cédex
France
J.P. Coutures (Laboratory Director)

Studies: crystal dynamics and phase transitions, oxide ceramics, liquid and glass silicates

74. CNRS Laboratory
"Imperfectly Crystalline Solids"
1A, rue de la Ferollerie
45071 Orleans Cédex 2
France
Telephone: 38-63-39-37
H. van Damme (Laboratory Director)

Studies: carbon materials, intercallation graphite compounds, oxides and silicates, mineralogy of clay structures, organic conductors

75. Institut (Max von) Laue (Paul) Langevin (ILL)
Avenue des Martyrs, BP 156X
38041 Grenoble Cédex
France
Telephone: 76-97-41-11

Involved in high-intensity neutron diffraction source, low-angle neutron diffraction studies. The ILL institute is funded by UK, France, Germany, and Italy.

76. Centre de Recherches d'Unieux (UNIREC)
BP 34-42701 Firminy
France
Telephone: 77-40-33-65
Telex UNIREC 307466F
R. Levegue (Manager, Surface Treatment Department)
C. Chabrol

Studies: Surface treatments by ion implantation and laser treatments (see ESN 41-5:271-273 [1987], "Metal Surface Treatment, UNIEUX, France"; also see Surface Properties of Materials, page 4)

77. Ecole Nationale Supérieure des Mines St. Etienne
158, cours Fauriel
F42023 St. Etienne Cédex
France
Telephone: 77-74-10-47
F. Thevenot, Department Materials

Studies: carbides, borides, high-temperature ceramics, surface treatments by ion implantation (see ESNIB 88-03:53-57 [1988])

78. Ecole Nationale Supérieure des Mines de Paris
Centre des Matériaux
Locaux SNECMA: Route Nationale 7
B.P. 87 - G91003 EVRY Cédex
France
Telephone: 1-60-76-30-00
Michel Jeandin
M. A.R. Bunsell
M. Daniel Broussaud

Studies: composites (ceramic-ceramic), superalloys, diffusion bonding, gas turbine materials, powder metallurgy, carbon-fiber-reinforced polymer matrices (see Ceramic-Ceramic Composite Materials, page 3)

79. Laboratoire Leon Brillouin
nvr Spéctrometrie Neutronique
CEN Saclay
91191 GIF sur YVETTE Cédex
France
Telephone: 6-908-6460
Director: Professor M. Lambert
Scientist: J.P. Cotton

Equipment: Reactor "ORPHEE" (swimming pool type)

Studies: Neutron diffraction structural studies, small-angle neutron diffraction, incommensurate structures

80. Laboratoire de Minéralogie-Cristallographie
Université Pierre et Marie Curie et Paris VII
16, Marie Curie
4, place Jussieu
75230 Paris, Cédex 05
France
Telephone: 1-43-54-84-76
Director: J.F. Petroff

Scientists: H. Curien [Minister of Science in the present government] (crystallography), A. Authier (dynamic theory diffraction), G. Calas (glass studies)

Studies: crystal structures, crystal growth, defects in mineral structures, phase transitions

81. Laboratoire central des ponts et chaussées
nvr Service de Physique
58, Bd Lefebvre
75732 Paris Cédex 15
France
Telephone: (1) 532 31 79
Director: L. Picq

Studies: concrete, anticorrosion paints, sea water protective coatings

82. Laboratoire de Physique
nvr Faculté des Sciences des Solides
Batiment 510
Université de Paris-Sud 91405 Orsay
France
Professor Dennis Jerome

Studies: Organic electrical conductors

83. Laboratoire d'Adsorption et Reaction de Gaz sur Solides
U.A. CNRS 413
Ecole Nationale Superiéure d'Electrochimie et d'Electrométallurgie de Grenoble
Institut National Polytechnique de Grenoble
BP 75
38402 St. Martin d'Heres
France
Director: Ph. Touzain; Scientist, R. Yazami

Studies: Li-graphitic oxide cells, organic conductors, graphite intercallation compounds (sponsored by EdF [see note in item 84])

84. Electricité de France (EdF)
1, ave. du General de Gaulle
92141 Clamart Cédex
France
Telephone: 765 3200

EdF has several research divisions, at different locations. The division Matériaux des Electrotechniques (at Clamont) is under the direction of L. Deschamps, and carries out studies of material conductors, nonlinear electrical resistance materials, insulators, magnetic materials, composites, adhesives. Metallurgical studies are carried out in the division under the direction of S. Masson at:
Les Renardieres
Route de Sens
Ecuelles
BP 1
77250 Maret-sur-Loing
France
Telephone: 970-68-20

85. Université de Rennes
Inorganic Chemistry Laboratory
Ave. de General Leclerc
35042 Rennes 35042
France
Professor Jacques Lucas
Studies: fluoride glasses

86. Université Pierre et Marie Curie
nvr Laboratoire d'Optique des Solides
4 Place Jussieu
F-75230 Paris Cédex 05
France
Professor Florin Abeles

Studies: metallic glasses

87. Laboratoire Métallurgie Physique Matériaux
Ecole Centrale de Lyon, BP 163
69131 Ecully Cédex
France
Professor D. Treheux

(see Surface Properties of Materials, page 4)

88. Le Carbon-Lorraine
BP 148-41 rue Jean Jaures
F-92231 Gennevilliers
France
Telephone: 799-90-41
Scientists: Mme Ades and M. Tilche
Research Director: Jacques Fourre

Studies and products: carbon products, graphites Their special carbon products are often unique and are used worldwide

89. Centre d'Etudes Nucléaires Grenoble (C.E.N.G.)
85X, 38041 Grenoble Cédex
France
Telephone: 76-88-32-24

M. Potard: studies on levitation

(see Levitation, page 33)

90. Centre d'Etude de Recherche de l'Industrie des Liants Hydrauliques
23, rue Cronstadt
Paris 15
France

Mme Regourd: studies of the structure and properties of cements and concretes

91. Mme Oberlin,
CNRS-Université
2, Avenue du President Pierre ANGOT
64000 PAU.
France

Very fine electron microscopy of carbon fibers, clays, and other materials.

92. Institut de Physique Nucléaire de Lyon (IPN)
69622 Villeurbanne
France
Scientist N. Moncroffe

High-energy isotope separator/accelerator

(see Surface Properties of Materials, page 4)

93. Centre d'Etude Nucléaires Saclay
Institut Nationale Science Technologie Nucléaire (I.N.S.T.N.)
91191 Gif-sur-Yvette Cédex
France

Sweden

Several reports are available concerning ceramic research in Sweden. The Swedish program on advanced engineering ceramics is described in references 16 and 17, page 40.

94. The Swedish National Board for Technical Development (STU)
(Styrelsen for teknisk utveckling)
Box 43200, S-10072
Stockholm
Sweden
Telephone: 87754000

Dr. Paul Forsgren, Head, Department of Industrial Processes; Bengt Simonson, Information Services; Leif Maartmann, Pulp and Paper

All the scientists speak English fluently, and many have spent extended periods of time working in US industry.

95. svenska Silikatforskningsinstitutet
Swedish Institute for Silicate Research
Roger Carlsson
Managing Director
Box 5403
S-40229 Göteborg
Sweden
Telephone: 31 18 48 57

Studies: complete range of industrial ceramics research

96. University of Stockholm
Arrhenius Laboratory
Department of Inorganic, Physical and Structural Chemistry
S-10691 Stockholm
Sweden
Telephone: 8-16-20-00
Professor Lars Kihlborg

Studies: W bronzes and bronzoids; crystal structures of fluoride, oxides of Cu, Nb, Ta, sintering of ceramics; Cu-Y alloys, solid electolytes; uranium oxide system, SiAlON with Y, La, Ce; Borides; high-pressure formation of nitrides

97. ASEA CERAMA
nvr S-91500 Robertsfors Sweden
TEl. 934 10510
Dr. Hans T. Larker (President)

Of special note: hot isostatic pressing (HIP) systems, some of the most advanced HIP systems worldwide.

98. Linköping University
nvr Department of Construction and Production Technology
581 83 Linköping
Sweden
Telephone: 13-281000
Professor Thomas Johannesson

Polymer-reinforced composites

99. Chalmers University of Technology
Göteborg
Sweden

Dr. Gordon Dunlop (Head, Materials Sciences; originally from New Zealand)

This is perhaps the most advanced research institute in Sweden (see ESN 87-02:57-59 [1987], "Materials Research in Göteborg, Sweden"). Studies by electron microscopy; ultrahigh vacuum; solid-state diffusion mechanisms, many aspects of materials sciences, engineering ceramics. Extensive cooperation with Swedish industry and government agencies.

100. Ceramic Materials
AB Sandvik Hard Materials
Box 42056
S-126 12 Stockholm
Sweden
Tel: 46 8 45 26 20

Directors of Research: Dr. B. Aronson and Dr. Thommy Ekstrom

Very successful research, development, and production of:

- *Advanced Engineering Ceramics*
- *Sialons*
- *Ceramic Cutting Tools*
- *Cemented Carbides*
- *SiC-reinforced Al_2O_3*

This industry is very successful on a worldwide scale. Their research is closely related to that of universities in Sweden and the UK (Newcastle).

101. United Turbine AB & CO., KB
N. Grangesbergsgatan 18
S-21450 Malmo
Sweden
Telephone: 040-80150
Manager: Johnny Rehn

Studies: Stress patterns in ceramic turbine blades, three-shaft ceramic gas turbines, development of a Si + SiC combustion chamber for a turbine engine stable at 1400°C.

102. AB Volvo Technological Development
Dept. 06460 A3
S-405 08 Göteborg
Sweden
Telephone: 46 31 59 66 25
Dr. Mats Dahlen

New Automotive Materials

(located in industrial campus alongside Chalmers University of Technology)

West Germany (Federal Republic of Germany [FRG])

103. Deutsche Forschungs und Vershuchsanstalt für Luft und Raumfahrt (DFVLR)
Linder Hohe
5000 Koln 90
West Germany
Tel: 02203-601-2450

This organization is responsible for materials research in Germany. Professor Dr. Wolfgang Bunk has been the coordinator for the past 10 years of the

German Government Program on Ceramics for Motors.

104. Technische Universität
nvr Hamburg-Harburg
Forschungsschwerpunkt 2
Postfach 90 14 03
D-2100 Hamburg-Harburg
West Germany
Professor Dr. Nils Claussen

Studies: ZrO_2 transformation toughening, composites, Lanxide composite formation (melt oxidation)

105. Technical University of Berlin
nvr Institut für nicht-mettallische werkstoffe Fachgebiet, Keramik
Inglische Strasses 20
100 Berlin 12
West Germany
Professor Dr. Hans Hausner

Studies: Fine ceramic powders

106. Institut für Werkstaffeforschung
nvr Postbach 906058, D-5000
Koln, 90
West Germany
(Professor Ziegler, Materials Section Head

107. Max Planck Institut für Metalforschung
Institut für Werkstoff Wischenschaften
Pulver-Metallische Laboratory (PML)
Heisenberg Strasse 5
7000 Stuttgart 80
West Germany
Director: Professor Dr. Gunther Petzow
Scientists: Dr. Richard J. Brook, W. Mader, H. Schubert, G. Schneider

This is the major ceramics laboratory in West Germany; see Ultraclean Ceramic Laboratories, page 32, and Nitride Ceramics, page 3.

Studies: ZrO_2-strengthened ceramics, Be single crystals, thermal shock and thermal fatigue studies, laser flash diffusivity measurements, polymer precursors for non-oxide ceramics, whisker-reinforced ceramics, the corrosion of ceramics, hard materials, pressureless sintering of AlN, high-purity metals and ceramics, magnets based on Fe-Nd-B, formation of fine ceramic powders.

108. Feldmühle AG
nvr Werk Sudplastik u. -keramik
Abt. Forschung u. Entwicklung
Postfach 23-29
Fabrikstr. 23-29
D-7310 Plochingen
West Germany
Dr. Ulf Dvorak

Studies: whisker-reinforced ceramics, ceramic powders

109. Universität Dortmund
nvr Postfach 500
D-4600 Dortmund
West Germany
Dr. R. Steinbrech

Studies: Mechanical properties of Al_2O_3 and other ceramics

110. Daimler-Benz A.G.
nvr Stuttgart unter Turkheim
Post Box 202
7000 Stuttgart 60
West Germany
Telephone: 0711-173427
E. Tiefenbacher

Industrial studies of ceramics for gas turbines

111. Technical University Hamburg-Harburg
nvr Forschungsschwerpunkt 2
Postfach 90 14 03
West Germany
Professor P. Greil; (recently moved from MPI Stuttgart)

112. Karlsruhe Establishment (Joint Research Center [JRC] of the Commission of European Communities
Linkenheim
7500 Karlsruhe
Postfach 2266
West Germany
Telephone: (07247) 84366
Dr. Joe Magill

(see Levitation, page 33)

113. Kernforschungszentrum Karlsruhe GmbH
PO Box 36 40
D-7500 Karlsruhe
West Germany
Telephone: 07247-822806
Dr. C. Politis

Studies: amorphous metals, superconductivity

114. Max-Planck-Institut für Metallforschung
Institut für Werkstoffwissenschaften
Seestrasse 92
7000 Stuttgart 1
West Germany
Dr. W. Mader

Studies: metal-ceramic interface, electron microscope lattice imaging (see ESNIB 88-01:41-44 [1988], "Bonding Metals to Ceramics, Stuttgart")

115. Deutsche Keramische Gesellschaft (DKG)
nvr Postfach 12 26
menzenbergenstr 47
D-5340 Bad Honnef
West Germany
Telephone: 022-241-71038 or 022-241-71039
Dr. Markus Blumenberg

116. Hoechst AG
nvr Postfach 80 03 20
D-6230 Frankfurt a.M. 80
West Germany
Dr. M. Peuckert

Studies: Si_3N_4-based ceramics

Italy

117. University of Rome,
"la Sapienza"
Dipartimento di chimica
Piazzale Aldo Moro
5-00185 Roma
Italy
Telephone: 39 6 4991
Dr. D. Gozzi

Studies: ceramic electrolyte cells, high-temperature oxidation of metals (see ESNIB 88-01:38-41 [1988])

118. Centro Richerche Fiat
Materials Department
Stada Torino 50 10043
Orbassano
Italy
Dr. Paulo Antona (laser treatment of Al alloys)
Dr. Angelo Giachello (ceramics in engines)

(see ESNIB 88-03:52-57[1988], "Wear Resistant Materials")

119. Osservatorio Astrofisico
Citta Universitaria
95125 Catania
Italy
Dr. Valerio Pirronello

Studies: ion bombardment of silicates

120. Joint Research Centre (JRC)
Commission of European Community (CEC)
21020 Ispra, Varese
Italy
Telephone: 39-332-78-91-11
Dr. Manes (Director, Material Sciences)
Dr. Manara (Head, Surface Sciences)
G. Piatti (Head, Metallurgy Section)

There is an extensive Materials Science Department. An ion foundry is being set up consisting of a 200-keV implanter with laser treatment facilities, depositions, and surface analysis by RBS, SIMS, SAM. (Research Program under review at present by CEC)

121. University of Padova
Department of Physics, Galileo Galilei
via Marzolo 8
35131 Padova
Italy
P. Mazzoldi (Head Section)
A.V. Drigo

Studies: implantation, irradiation glasses, semiconductors, metals. Use is made of the accelerators of LNL (see next address, 122). (see ESNIB 88-06:22-24 [1988])

122. Laboratori Nazionali di Legnaro
Legnaro
Padova
Italy
INFN (LNL)

This laborataory is about 10 kilometers from the University of Padova. Its accelerators are available for all Italian universities.

The Netherlands and Belgium

123. University of Technology
Post Bus 513
NL-5600 MB Eindhoven
Netherlands
Telephone: 31-40-47-91-11
Professor R. Metselaar (President, European Ceramic Society)

Studies: ceramic materials, ceramics for MHD system

124. Commission of the European Communities (CEC)
Joint Research Centre (JRC)
P.O. Box 2
1755 ZG Petten
Netherlands
Telephone: (022 46) 5656
Dr. E.D. Hondros (Director)
Professor Marcel Van de Voorde (Head, Materials)

The initiative for much of the materials science studies at the several JRC's probably comes from this JRC. (see ESNIB 88-03:57-59[1988])

125. Laboratorium voor Fysische Chemie
Vrije Universiteit Brussel
Pein laan 2,
B-1050 Brussels,
Belgium
Dr. J. Drowart

Studies: thermodynamics of inorganic systems at high temperatures by Knudsen cell-mass spectroscopy. (see ESN 88-01:38[1988])

126. Nuclear Research Centre (SCK/CEN)
Boeretang 200
B-2400 MOL
Belgium
Telephone: (014) 311801
A.J. Flipot

(see ESN 89-01:64[1987], "Ceramics Research Mol., Belgium"; see also Ultraclean Ceramic Laboratories, page 32)

127. Geel JRC (CEC)
Steenweg op Retie
2440 Geel,
Belgium
Telephone: 571211

This is one of the four CEC research centres specializing in industrial technologies, reference materials, nuclear measurements. Geel JRC is equipped with linear accelerators.

Switzerland

128. Ecole Polytechnique Fédérale de Lausanne (EPFL)
32, chemin de Bellerive
CH-1007 Lausanne
Switzerland
Telephone: (41)-21-472847
Professor H.H. Kausch (polymers)
A. Mocellin (ceramics)
A. Roulin-Moloney (polymers)
W. Kurz, Director of Center de Traitement des Matériaux par Laser (CTML)

(see ESNIB 88-04:26-28[1988], "Materials Research in Lausanne, Switzerland"; see also Laser Beam Treatment of Surfaces, page 31)

129. IBM-Zurich Research Laboratory
4, Saumerstrasse
CH-8803 Ruschlikon
Switzerland
Dr. Dieter Pohl

Very fine scanning tunnelling and atomic force microscopy.

Greece

130. University of Crete
Physics Department
71409 Iraklion
Crete
Greece
Telephone: (081) 236.589
G. Kiriakidis (semiconductors)
Georges Fythas (polymers)
Panos Tzanetakis (ion cluster beams)
Farantos (biotechnology)
Stelios Orphanovdakis (computer sciences)
C. Fotakis (lasers)
Zacharias Hatzopoulos (molecular beam epitaxy)

This is an extremely active research group, well set-up, with very well selected research programs.

131. School of Physics and Mathematics
nvr Aristotle University of Thessaloniki
Odos Panepistimiou Thessalonika
Greece
Director: Professor N.A. Economou (solid-state physics)

132. Democritus University of Thrace
School of Engineering
67100 Xanthi
Greece
Telephone: (0541) 26476
Professor A. Thanailakis (solid-state studies).

133. University of Patras
Department of Physics
Patras
Greece
Telephone: (061) 993.134
Scientists: E. Mytilineou, M. Roilos, Takis Kounavis

The research studies undertaken in Patras are most impressive.

Studies: optical memory materials, crystalline-amorphous transition, chalcogenide semiconductor properties, sputtering systems

(see Science Newsbrief 6-5[1988] and ESNIB 88-04:28 [1988], "Chalcogenide Thin Film p-n Devices, Patras, Greece")

134. Nuclear Research Centre
DEMOKRITOS
Agia Paraskevi
Athens 15310
Greece

Dr. Papastaikordis (Al alloys, Al-Li alloys)
Aris Terzis (crystal structure determination of organic superconductors)

135. General Secretariat of Research and Technology
14-18, Messogion Str
115 10 Athens
Greece
Telephone: 77 53 834
Directors: E.N. Economou and G.N. Papatheodorou.

This organization is responsible for the fine research institutes at Iraklion, Patras, Thessaloniki, and Athens.

136. Institute of Chemical Engineering and High Temperature Chemical Processes
PO Box 1239
University Campus
GR 26110 Patras
Greece
Telephone: 061-993-253
Director: G.N. Papatheodorou (see item 135, above)

Studies: catalytic materials and their characterization, oil recovery tests, the study of porous materials, filtration of liquid-solid suspensions, spectroscopy (Raman, lasers, UV laser-induced fluorescence), plasma techniques

Research Programs are related to the petrochemical industry, high-temperature and new materials, enhancement of vapor pressure by the formation of complexes, hydrogenated amorphous Si. Comment: This is an excellent research center.

137. National Metsovio Polytechnic
Physics Laboratory III,
Zographou University Campus
Athens 15773
Greece
Telephone: 77-00-672
Professor E. Anastasakis
Dr. Serafetinides

Studies: pulse laser (CO_2, N_2, F) construction, high-temperature and high-pressure studies of semiconducting IV-IV, III-V and insulating materials, by Raman and by photoluminescence spectroscopic techniques, laser annealing Si, magnetic semiconductors $Zn_{1-x}Mn_xS$

Spain

138. Consejo Superior de Investigaciones Cientificas (CSIC)
Serrano, 113
28006 Madrid
Spain
Director: Ignacio Fernandez de Lucio

This is the controlling body of the many research institutes in Spain. (see ESNIB:88-04:21-23 [1988])

139. Instituto de Ciencia de Materiales (ICM)
Serrano, 144
2806 Madrid
Spain
Telephone: 261 88 06
Scientists: Jose L. de Segovia, Dr. J.M. Serratosa, Dr. F. Soria

This is an active, successful research center (see ESNIB 88-04:21, "Materials Research Institutes in Madrid, Spain." [1988])

140. Instituto de Acustica (CSIC)
Centro de Fisica Aplicada
Serrano, 144, Madrid
Spain
Telephone: 261 88 06
Director: Jaime Pfretzschner Sanchez

(see ESNIB 88-04:21-23 [1988])

141. Instituto de Ceramica y Vidrio (CSIC)
Arganda del Rey
Madrid
Spain
Telephone: 871 18 00
Drs. J. Jurado, Carmen Pasual, and Pedro Duran

(see ESNIB 88-04:23 [1988], "Ceramics Research Institute, Madrid, Spain")

142. Materials Research Institutes, Barcelona
nvr Mark Franques S/N
08028 Barcelona
Telephone: (93) 6920200
Director: Carlos Miratvilles

143. Materials Research Institute, Arajon
nvr Flad de Ciencias
J0001 Zaragoza
Telephone: (976) 560741
Director: Rafael Alcala

144. Materials Research Institute Sevilla
nvr Apto 1115
41071 Sevilla
Spain
Telephone: (954) 628961
Director: Guillermo Momera

Turkey

Applied materials science in Turkey is reviewed in *ONREUR Report* 7-013-R (1987). The following is a short list of scientists and organizations in Turkey.

145. Metalurji Muhendisleri Odasi
nvr (Metallurgical Engineering Society)
Konur Sokak 4/1
Yenişehir, Ankara
Turkey
Telephone: 18-12-75
Miss Neela Yikilmaz (President)

146. YÖK (Yuksek Öğretim Kurulu)
Ankara,
Turkey

This organization is responsible for overall direction of the Turkish university system.

147. Ankara Nuclear Research and Training Center
Besevier, Ankara
Turkey
Telephone: 23 44 39
Professor Dr. Ugur Buget, Director

(see ONRL Report 7-013-R [1987], "Applied Materials Science in Turkey")

148. Turkiye Bilimsel ve Teknik Anastirma Kurumu (TÜBITAK)
Ataturk Bulvari 221
Kavaklidere, Ankara
Turkey
Dr. Mehmet Tomak, Scientific Director of the Materials and Solid-State Sciences Division

This organization is responsible for the funding of scientific and technological research activities in Turkey.

149. Marmara Research Institute
P.O. Box 21 Gebze, Kocaeli
Turkey
Telephone: 9(1991) 1678
Professor Dr. Yilmaz Tokad, Director
Professor Dr. Sefik Gulec, Head, Materials Research Department

Organized by Tübitak

(see ONRL Report 7-013-R [1987])

150. Electronics Research Institute
Tübitak Ankara Elektronik Arastirma ve Gelistirme Enstitusu Muduru
Middle East Technical University (METU)
Ankara
Turkey
Professor Dr. Ayhan Tureli, Director

(see ONRL Report 7-013-R [1987])

This is located on the university of METU campus alongside the Department of Electrical Engineering.

151. Mineral Research and Exploration
Maden Tetkik ve Arama (MTA)
Eskişehir Yolu, Ankara
Turkey
Telephone: 23 42 55
Dr. Fethullah H. Ozelcl, Department of Geophysics

MTA has very extensive laboratories, and conducts field work covering all aspects of geological survey and mining engineering. Turkish is the principle language at MTA.

152. Hacettepe University
Ankara
Turkey
Telephone: 90-41-23-03-91
Dr. Atilla Aydinli (physicist)

Studies: surface sciences (in collaboration with University of Padova, Italy)

153. Department of Geological Engineering
Middle East Technical University (METU)
Inönü Bulvari, Ankara
Turkey
Tel: 23-71-00
Chairman: Professor Norman

This is a very active department (All instructions are in English).

154. Department of Physics
Middle East Technical University (METU)
(Orta Dogu Teknik Universitesi)
Ankara
Turkey
Hüsnü Özkan (Elastic properties of crystalline solids)
Aymelek Özer (Archeology and electron spin resonance studies)

This is probably the most important technical university in Turkey. All instructions are in English. (see ONRL Report 7-013-R [1987])

Austria

155. IMS Ion Microfabrication Systems
nvr Gesellschaft m.b.H.
Schreygasse 3
A1020 Vienna
Austria
Mr. Hans Loschner (Ion beam lithography)

156. Institut für Physikalische Chemie
nvr University Wien-Osterreich
Austria
Dr. J.C. Schuster (N-ceramics)

157. Institute for Chemical Technology of Inorganic
nvr Materials
Technical University of Vienna
Karlsplatz 13
1040 Vienna 4
Austria
Dr. W. Langauer (N-ceramics)

158. Boltzmann Institute for Solid-State Physics
nvr Kopernikusgasse 12
Vienna VI
Austria
Professor Karlheinz Seeger (semiconductors, organic conducting materials)

159. Austrian Research Center
nvr Seibersdorf
A-1082 Vienna
Austria
Telephone: 0222-42-75-11

160. Metalwerk Plansee
nvr Reutte, Tirol
Austria
Telephone: 05-67-222-41-281
Director: Dr. H. Bildstein, Dr. H. Wurzinger

Studies: graphite-metal bonding, special metals

This is a very important organization producing some unique materials.

Hungary

161. Central Institute for Physics
nvr POB 49
H-1525 Budapest
Hungary
Scientists: Csaba Hajdu, Miklos Fried, Endre Kotai,

At many scientific meetings scientist from this institute present data and describe work of a very high quality.

Studies: semiconductors

162. Solid-State Chemistry Department
nvr Research Laboratory for Inorganic Chemistry
Hungarian Academy of Sciences
Budapest XI, Budaorsi ut 45
PO Box, H-1502 Budapest, Pf 132
Hungary
Dr. L. Bertoti
Nitrogen Ceramics

Portugal

163. Universidade de Lisboa
nvr Centro de Fisica Nuclear
Av. Prof. Gamma Pinto, 2
1699 Lisboa Codex
Portugal
Scientists: Dr. Jose Carvalho Soares
Dr. Manuel Ribeiro da Silva

164. Laboratorio de Fisica
nvr Universidade do Minho
P-4719 Braga Codex
Scientists: Dr. M.P. dos Santos, Professor Jose de Almeida, Dr. Marta M. Duarte Ramos, Professor M. Isabel Ferreira, Dr. Fernanda Guimaraes

165. LNETI-Dipart. Fisica
nvr EN 10
2685 Sacavem
Portugal
Scientists: Eduardo da Costa Alves, Antonio Sequeira, Dr. Fernanda da Silva

166. Dept. Eng. Mecanica
nvr Faculdade de Ciencias
Universidade de Coimbra
3000 Coimbra
Portugal
Dr. Rui da Silva Vilar

East Germany (GDR)

167. Zentralinstitut für Festkorperphysick und
nvr Werkstofforschung der AdW der DDR
Helmholtzstr 20
Dresden DDR-8027
East Germany
Dr. M. Herrmann

168. Akademie der Wissenschaftern der DDR
nvr Zentralinstitut für anorganische Chemie
Rudower Chaussee 5 Berlin-Adlershof DDR-1199
East Germany
Dr. Dietmar Linke

Poland

169. Instytut Metalurgii
nvr Akademia Gorniczo Hutnicza
30-059 Krakow
Poland
Al. Mickiewicza 30
Professor S. Gorczyca

170. Instytut Inzynierii Materialowej
nvr Politechnika Warszawska
Warszawa
ul. Traugutta 84
Poland
Professor M. Grabski

171. Instytut Ceramiki i Inzynierri Materialsowej
nvr Akademia Gorniczo Hutnicza
30-059 Krakow
Poland
Al. Mickiewicza 30
Professor R. Pampuch

172. Instytut Inzynierii Materialowej
nvr Politechnika Slaska
Katowice
Poland

4. ONREUR Workshop Summaries and Recommendations

Several conferences and workshops on material science topics, recently sponsored by ONREUR, have led to reviews or sets of recommendations. The summaries and recommendations of these workshops constitute valid reviews of their subjects, frequently with a European perspective. For this reason, I believe it is useful and appropriate to reproduce two of those "summaries and recommendations" as part of this total "source notes" report. Two of them follow, the first on engineering materials at very high temperatures, the second on advanced concepts for ceramic toughening.

Engineering Materials for Very High Temperatures.

A workshop was organized by ONREUR on this topic in 1987, and the recommendations were subsequently discussed and reviewed by a small committee discussion group in 1988, consisting of P. Popper, M. Lewis, D.P. Thompson, and L. Cartz. The abstract and revised recommendations (summary comments) are reproduced here. The complete workshop proceedings are issued as *ONRL Report* 8-016-R (1988).

All possible materials and treatments were considered at the workshop, including N-ceramics, ceramic-ceramic composites, carbides, borides, silicides, and refractory silicates.

Abstract. The limitations of present-day materials were pointed out and future requirements with significantly higher temperature capability were indicated. The properties demanded were high strength, toughness, creep, and oxidation resistance at high temperature, but cost-effective processing and reliability were equally important.

Among the ceramic materials discussed, silicon nitride-based ceramics allow use at up to about 1250°C, which might be extended up to 1400°C. Silicon carbide has a better performance at high temperatures but suffers at present from a low fracture toughness, which needs to be improved. Carbon-containing materials could be used at temperatures of perhaps 2000°C, but for use of these materials in air, protection against oxidation needs to be provided, which is not an easy problem to solve. The same applies to the protective coatings on refractory metals, which require a better understanding of their adhesion and diffusion properties. Among new materials to be studied, the silicides and borides were suggested.

The fracture toughness of ceramic materials might be increased by the incorporation of fibers and whiskers; presently this approach is limited by the availability of suitable fibers and whiskers – current composite materials do not display better fracture toughness properties at high temperatures than monolithic ceramics. However, there are signs of improvement of this situation.

The mechanism of sintering aids which do not form liquids, as used in the sintering of silicon carbide, requires elucidation.

Recommendations of the ONREUR workshop. The recommendations have benefited from further discussions and suggestions from Drs. Lewis, Thompson, Cartz, and Popper (early 1988).

Near-term Studies.

- Increasing the temperature ceiling of Si_3N_4-based monolithic ceramics to at least 1400°C in oxidizing conditions, using stable crystalline sintering residues and HIP processing.
- Improving the fracture toughness and strength of SiC-based ceramics, formed by solid-state sintering, by particulate or whisker dispersions, while retaining the good creep-rupture and oxidation resistance of the sintered matrix.
- Further development of SiC or C-based fibrous composites with respect to stability at temperatures of 1200°C, especially in oxidizing conditions (e.g., by coatings for C-C composites and the use of the newly emerging stoichiometric SiC fibers).

- Development of coatings on metals (e.g., superalloys) of refractory silicates (celsian, for example) of matched thermal expansion behavior, made by the glass-ceramic route, replacing existing oxide coatings.

Longer Term Studies.

- The development of a range of new particulate dispersants, with controlled morphological anisotropy, and chemical compatibility with Si_3N_4 and SiC-based matrices, designed to extend the principle of "whisker-toughening."
- Further development of high-stability fibers, such as stoichiometric SiC, and of nonreactive interfaces with refractory matrices. This may be achieved by coatings or by using lower temperature fabrication such as the "sol-gel" route for oxides, or "reaction-bonding" for Si_3N_4. The present-day limited choice of fibers is a severe handicap; it would be very useful to have fibers of materials such as BN, BC, and AlN.
- Development of shaping/fabrication procedures, especially for fibrous composites, with an emphasis on property targets for specific component application
- Develop a better understanding of the basic mechanisms involved in sintering, both of monolithics and composite matrices, and of high-temperature deformation and fracture. In "dispersed-phase" composites, the relative contributions of different toughening mechanisms should be investigated.
- Develop an understanding of coating cohesion and substrate interdiffusion.
- Examine the properties of other high-temperature materials, such as those based on borides, silicides, and carbides.
- Develop methods of flaw detection in ceramics to permit the study of the smallest flaws under stress and environment, as well as to obtain more consistent properties in ceramic materials.
- There is a lack of data of the mechanical properties of ceramics above 1400°C, and data is required certainly up to 1600°C. Measurements techniques to acquire this data must be developed.

Advanced Concepts for Ceramic Toughening

This workshop summary was prepared with the collaboration of Session Chairs at the meeting by Professor R.J. Brook and Dr. H. Schubert, Max-Planck Institute für Metallforschung, Institute für Werkestoffwissenschaften.

The objective of the ONREUR workshop held in April 1988 at Schloss Weitenberg, West Germany, was to clarify current understanding of toughening mechanisms in ceramics and to identify future patterns of work that are needed in order to develop materials with the mechanical properties required for applications.

The meeting was divided into four sections concerned, respectively, with the theory of toughening mechanisms, with the role of interfaces in toughened microstructures, with the requirements of processing, and with the transfer of these concepts into industrial practice.

It was recognized that different sectors of the subject were at very different levels of development. Thus, work on transformation toughening had been brought to a level of maturity where significant issues remained but where the basic understanding was now sound. In contrast, work on fiber and whisker reinforcement was at a very preliminary level in terms of the understanding of the desired interface structure between the reinforcing phase and the matrix. There was, in particular, concern that high-temperature events in toughened microstructures should be so little explored.

The issue of fatigue was recognized by the workshop participants as of great significance. The possibility that attempts to toughen microstructures necessarily brought penalties in respect to fatigue performance was explored; this was seen as a topic requiring urgent investigations. In respect to processing it was clear that good progress had been made in the evolutionary development of ceramic fabrication methods. While this could be expected to continue, the opportunities offered by novel processes, such as that of melt oxidation, were clear in respect to the added degree of flexibility which would arise from the availability of alternative methods.

The meeting was encouraging in that it demonstrated the progress that could be made with a topic such as transformation toughening when the resources of the materials community were focused on its resolution. The meeting raised matters of real concern in respect to the possible fatigue penalty which could ensue from the absence of identified toughening mechanisms suitable for high-temperature applications. The two topics were seen as a suitable basis for future research programs which could then be reported at a subsequent workshop.

Toughening Mechanisms.

A.G. Evans, University of California at Santa Barbara

The session discussed four main mechanisms for improving the toughness of ceramic materials:

- Transformation toughening
- Toughening by ductile phases
- Toughening by brittle fibers and whiskers
- Toughening by microcracking

The most extensive discussion took place with regard to transformation toughening. This discussion first emphasized the lack of any concrete evidence in favor of toughening by ferroelastic transformations, although twinning effects that take place after transformation in monoclinic particles were regarded as a possible further contribution to the toughening of zirconia systems.

The topic of resistance curves (toughness as a function of crack extension) in transformation toughened materials was then considered.

The first conclusion reached was that the resistance curve is a function of specimen geometry and therefore that some standardization of geometry must be established in order to generate resistance curves useful for engineering design purposes, analogous to but not the same as the ASTM-standard that now exists for plain strain fracture toughness testing in ductile materials.

The discussion then moved to the concept of the transformation zone; this zone has implications for the underlying mechanism of transformation and, in turn, for the magnitudes of the slope of the resistance curve and of the steady-state toughening. The notable diversity of opinions and of results that can be seen to exist can in part be attributed to the fact that most observations are made in plain stress near the surface, whereas the toughness in resistance curve measurements really relies primarily on the plain strain zone. However, notwithstanding this difficulty, there is still a remarkable diversity in the experimental observations of transformation zones. Some results using interference fringes (D. Marshall, Rockwell International Science Center, Thousand Oaks, California) indicated a zone that was close in form to the dilatational zone albeit somewhat affected presumably by the shear component. In other cases (R.J.H. Hannink, CSIRO, Clayton, Australia), the completely different zone indicated that the transformation occurred in bands with failure then proceeding within the bands by a mechanism different from that usually used to describe fracture resistance. These results suggest that such materials may require a quite different description of fracture property than has heretofore been established.

Some recent calculations (Budiansky) of the resistance curve for a material that transforms as a result of the mean stress indicate a peak in the resistance curve before values settle back into a steady state. Professor M. Ritchie (University of California, Berkeley) presented some experimental observations that would tend to support these calculations. However, other experimental observations contributed from the audience were not able to confirm the existence of such a peak. In view of the importance of the slope of the resistance curve for the overall structural integrity of components made of transformation-toughened materials, further calculations for other transformation criteria, more careful experimental measurements of resistance curves, and the correlation between the two are certainly warranted.

The concept of synergism in toughening mechanisms was discussed. Recent calculations (Budiansky) have revealed that under certain conditions, when bridging zone mechanisms and transformation mechanisms operate simultaneously, it is possible to have a toughness that is synergistic – i.e., a multiplicative effect of the two individual mechanisms. The conditions are that the transformation zone must be greater than about 1/10th of the bridging zone if the synergism is to operate. Experimental validation of these calculations exists in partial form through work done (Becher and N. Claussen, TU Hamburg-Harburg) in which both transformation toughening and bridging toughening by whiskers has been reported. Other results have failed to confirm the existence of synergism.

In view of possible confusion about the actual mechanisms operating in the materials evaluated, and in view of the need for certain conditions to be satisfied in order that multiplicative effects may occur, it is now important to make experimental measurements of synergism in materials that are transformation toughened and whisker toughened or are transformation toughened and toughened by metal phases. This is an exciting opportunity, simply because of the enormous potential for further increasing the slope of the resistance curve by combining mechanisms.

In the area of toughening by ductile reinforcements, difficulties were seen in resolving theory and experiments. To explain several of the experimental observations, one requires ductile particles with flow stresses that are very high (x20) in comparison with the uniaxial yield strength. While a factor of 6 or so can be explained by the influence of the high elastic constraint on the deformation of the particles, the other factor of three must be explained if materials are to be designed from first principles.

One explanation (Sigl) was that the small ductile phases have an elevated flow strength that results from dislocation pile-up. However, caution was expressed by many participants with regard to the applicability of a single pile-up model to the large-scale deformation that occurs in these small plastically deforming particles during the fracture process.

There is thus an open issue as to why theory and experiment do not agree with regard to the toughening of ceramics by ductile phases; in view of the importance of this phenomenon for the development of high-performance structural materials, there is an urgent requirement for both experimental and theoretical developments in the near future.

Another explanation of the discrepancy is concerned with the trapping of cracks along the crack front by the ductile particles. Theoretical calculations (Rice) hope to provide some information about the magnitude of this crack trapping phenomenon. Experiments are urged wherein the plasticity of small ductile enclaves in a ceramic system can be explored; studies on actual composites that measure the magnitude of the bridging zone that exists in the presence of the ductile reinforcements and which determine the plastic stretch at which the ductile phases fail are also important. Insight is needed concerning the nature of the ductile phases that give the optimum increase in toughness. In this regard, experimental work (Ashby) and calculations have already indicated that a minimal degree of debonding between the ductile phase and the ceramic matrix is important if the degree of plastic stretch and hence the toughness imparted by the ductile phases are to be optimized. This reduces the elastic constraint to some extent but greatly exaggerates the plastic stretch to failure; since the overall toughening is a product of the flow stress and the plastic stretch, the overall toughening imparted by the particles is improved. This concept needs to be further explored by experiment on a range of different ductile phase toughened systems.

On the topic of toughening by brittle fibers and whiskers, the critical role of the interface was emphasized. Research to date has indicated that the fibers must debond from the matrix as the matrix crack propagates up to the interface; for fibers and matrix having the same elastic modulus, this requires that the critical strain energy release rate for the interface be less than about 1/4 of that of the fiber. The effect of modulus mismatch on this criterion has yet to be established. This debonding represents a prerequisite for the achievement of high toughness in brittle fiber or whisker-reinforced ceramics. Beyond this requirement, the sliding resistance of the debonding interface must also be low and this requires that the friction coefficient of the debonded layer also be quite small, perhaps less than about 0.1. Presently, this is accomplished by using carbon or boronitride as the coating layer on the fiber. However, these materials are not stable at high temperatures and alternative coatings must thus be developed which satisfy the appropriate debonding and sliding criteria. Examples of coatings that may be appropriate include some refractory metals, such as niobium, some intermetallics, such as niobium-aluminides and possibly spinel-layers.

Residual stresses are also important in governing the mechanical properties and the toughness of brittle fiber and whisker-reinforced systems. However, the influence of the residual stress is very sensitive to the manner in which the debonding takes place at the interface and the manner in which the fibers themselves fail. Details have been worked out and presented (Dr. D. Marshall, Rockwell Int. Science Center, Thousand Oaks, California): estimation of the appropriate residual stresses needed for high-performance composites requires detailed understanding of the way in which the fibers and/or the whiskers behave in the composite itself.

In the most general sense it seems that rather small residual stresses are desirable (close matching of the thermal expansions of the fiber and of the matrix); these stresses should furthermore be tensile to encourage debonding and to allow relatively small sliding stresses across the debond.

It was also noted that aligned fibers are able to give a much higher contribution to the toughness than randomly oriented whiskers; the latter tend to fail by elastic bending in the crack wake and are therefore unable to exhibit much pull-out. In contrast, aligned fibers are able to fail at considerable distances from the matrix crack plane and therefore exhibit substantial pull-out. Such arguments are consistent with experimental results for a number of systems which indicate that the toughness of uniaxial reinforced composites can reach levels of 25 to 30 MPa$\sqrt{m}$; the best toughness reported in the case of whisker-reinforced materials is about 9 to 10 MPa$\sqrt{m}$.

Finally, on the topic of microcrack and crack bridging toughening in polycrystaline oxide materials, it is apparent that some degree of controversy still exists. It is certainly true that effects do occur in the crack wake either due to intact grains or perhaps due to the locking of grains that have failed leading to further fracture then occurring in the crack wake. This frictional locking can occur in materials that have thermal expansion anisotropy wherein residual strains exist in the polycrystralline material. However, models of a rigorous nature do not presently exist for this process; no realistic comparison between theory and experiment exists to validate the role of such locking grains on the overall fracture resistance.

The existence of microcrack zones as a form of toughening has also been postulated and verified in the case of alumina/zirconia. However, the postulates that have been put forward for other systems such as polycrystalline alumina have not really been verified because of the difficulty of experiments designed to explore the existence of the microcrack zone. At this point, therefore, the importance of microcrack toughening compared with crack bridging toughening remains unclear in many of the polycrystalline oxides for which resistance curves exist. The resolution of this issue will clearly require further modeling and experiments that can be more accurately compared with theoretical calculations; the relative importance of microcracking effects and of crack bridging effects in this type of material can then be understood.

Interfaces.

A.H. Heuer, Case Western Reserve University, Cleveland, Ohio

This session was devoted to interfaces and microstructures and to their involvement with toughening mechanisms in ceramics. The opening review (M. Ruhle, University of California, Santa Barbara) focused on microstructures with discussion of silicon carbide fiber-reinforced and silicon carbide whisker-reinforced glass, alumina and silicon nitride matrices; it also reviewed model experiments (Ashby) on lead wires in pyrex glass. Most of the whisker-reinforced composites used Tatcho or Arco whiskers, which have a variable diameter and an amorphous SiO_2 -rich surface layer and a lower-density core region.

An interesting feature was that the silicon carbide whiskers in alumina matrices were under compression, whereas those in silicon nitride matrices were under tension. Experiments described in the review involved putting indents in thin foils and measuring the debonding, crack deflection, and crack bridging associated with the propagation of the main crack. The composite materials were all prone to chemical reactions at temperatures at about 1000°C. The treatment emphasized the desirable level of interface debonding and the degree of damage associated with propagating cracks in fiber- and whisker-reinforced composites.

Professor Hutchinson (Harvard University, Cambridge, Massachusetts) then spoke on interface mechanics and emphasized the need for a complex toughness coefficient K (involving (-1 1/2) when an interface between two dissimilar materials was involved; while this served to complicate matters, the complication could be handled in most practical cases. The most important aspect of the complex K was that interface cracks were always subjected to mixed mode loading. Hutchinson also reviewed the notion of interface toughness for circumstances where interfaces were rough and where the kinking of cracks out of interfaces occurred.

R.M. Cannon (University of California, Berkely) described some imaginative model experiments involving metal/glass sandwiches made by the bonding of two glass plates, onto each of which copper had previously been evaporated. The presentation of log v (ms^{-1}) against G(Jm^{-2}) rather than of log v against K ($MPa\sqrt{m}$) was preferred as a means of presenting the data so that a wider audience could understand the important aspects of crack propagation [v for velocity and G is the shear modulus]. It was found that, particularly at lower deposition temperatures in the range 400-600°C, great variability in joint toughness (values between the G_C of glass and 20 percent of this value) could be observed; this effect arose from monolayer impurities picked up as a consequence of the quality of vacuum used in fabricating samples.

Cannon emphasized the very large contribution of G_C provided by the plasticity of the metal phase, and further pointed out the lack of a good failure criterion for interface failure, the concept of a constant GC in the K_I/K_{II} space not being rigorously justified. He further showed that by deliberate introduction of defects into an interface (incorporation of voids; forcing of cracks to undergo "meandering"), there was the possibility of improving interface fracture toughness by 1 to 2 orders of magnitude.

W. Mader (Max-Planck Institut für Metallforschung) spoke on the evaluation of the residual stresses arising from the thermal expansion mismatch in silicon carbide whisker reinforced alumina. The misfit caused radial and tangential strains which could be observed in the TEM; several analyses including Green's function methods and finite element techniques could be used for a quantitative evaluation. It was comforting that the strains deduced from the thermal expansion mismatch, with the assumption of linear elasticity and with no allowance for stress relaxation, agreed well with those expected from the thermal expansion mismatch. The presentation emphasized that residual stresses were always present in fibrous composites even if they were rarely taken into account in models. It was further emphasized that the residual stresses at the tips of whiskers could be particularly dangerous, in view of the large stress concentration expected.

D.R. Clarke (IBM Yorktown Heights) discussed the intergranular phase in silicon nitride and reported experiments in which samples of silicon nitride were quenched from 1450°C and compared with samples that had been slowly cooled to room temperature. It was clear that the quenched samples had rounder grains and a much thicker intergranular phase than those which had been slowly cooled. This result emphasized the dangers of room temperature characterization when high-temperature performance was at issue.

The final formal presentation (D. Michel, CNRS, Vitry-sur-Seine, France) was on eutectics interfaces; silica glass/mullite, tetragonal zirconia/alumina and cubic zirconia/magnesium oxide eutectics had been studied. These provided good model systems for looking at the way in which cracks propagated through materials containing dissimilar phases. The knowledge from such model experiments could be effectively integrated into discussion of real composite materials.

During the discussion period, attention was given first to the need for better testing procedures, (particularly at high temperatures), to the fact that we are a long way from optimizing the reinforcement phase for fiber- and whisker-reinforced ceramics, and thirdly to the fact that the chemistry of interfaces can have a serious influence on performance, particularly where reactions between fiber and matrix (whether leading to diffusion profiles or to actual reactions) were involved. Diffuse interfaces were considered in virtually none of the models; the distinction between diffusion involving chemical gradients adjacent to physically sharp interfaces and diffusion at genuinely diffuse interfaces was seen as important.

The overall impression from this session was that the field was ripe for further experimental and theoretical advance. Broad outline criteria were available for designing good composites but important questions, such as the optimum level of interface bonding, remained unresolved and required further intensive experimental and theoretical effort.

In comparing the session with the earlier session devoted to Toughness/Microstructure, and more distantly, with the meeting that had been held in 1982 at Scholo Ringberg, it seemed clear that the level of question raised in connection with transformation toughening had become highly sophisticated over the 6-year period; the nature of the questions asked in connection with fibrous composites had, in contrast, remained similar to that found at Scholoβ Ringberg 6 years ago. A further workshop 3-years hence, devoted to the theme of interface composites would in the light of this experience be a rewarding and appropriate event.

Discussion session.

"The Significance of Toughness for the Acceptability of Ceramics" D. Marshall, Rockwell International Science Center, Thousand Oaks, California.

The purpose of this session was to answer or at least address two questions:

1. Is toughness the parameter to maximize for design purposes
2. If so, what value of toughness is needed in order to expand the applications of ceramics

The session began with a presentation (M. Ritchie, University of California, Berkeley) on fatigue in toughened systems. Beginning with a general discussion of toughening and fatigue, he pointed out that toughening which involved hysteresis in loading/unloading led to fatigue; toughening also changed the fatigue curve (plot of fatigue crack propagation rate against the stress intensity range, $\Delta K = K_{max}-K_{min}$, encountered in the fatigue cycle) with respect to the ΔK axis in a way that was dependent upon the type of toughening mechanism. As an example, crack deflection added a constant value to all the ΔK's so that the plot of crack growth rate as a function of ΔK was simply translated along the ΔK axis. Zone toughening mechanisms, as in transformation-toughened zirconia, multiplied all other ΔK values by a constant. Thirdly, contact shielding, a prevalent mechanism in metallic systems, shifted the curve more at low values of ΔK than at high values. The presentation next discussed fatigue measurements. For large cracks under cyclic tension loading in magnesia partially stabilized zirconia, the following results were emphasized:

1. Mechanical fatigue did occur with a steep fatigue curve and the threshold ΔK values were very dependent on the steady-state toughness of the material, e.g., a material with a toughness of 6 showed fatigue at ΔK values of about 3, whereas a material with a toughness of about 13 showed fatigue growth for values of ΔK about 8 $MPa\sqrt{m}$.
2. The fatigue effect was definitely shown to be mechanical in origin; several very careful experiments ruled out environmental effects.
3. Transient effects were observed when ΔK was changed after growing a crack over a long distance at constant ΔK. Decreasing ΔK gave a large reduction in growth rate, which then slowly increased to a new steady state. Increasing ΔK gave the opposite effect, namely a large increase in crack growth rate, which slowly declined again to the steady state. This result would be just as expected for a zone shielding mechanism, because the shielding would be dependent upon crack history. However, the effect was surprisingly large in that very small changes in ΔK gave very large changes in crack growth rate.
4. The mechanism of fatigue in these materials was not known; a somewhat surprising result was that even the overaged material, that was no longer toughened, exhibited fatigue.

The conclusion was that ceramics did exhibit fatigue and that this needed to be accounted for in design. A positive aspect was that this had long been the case for metals and that fatigue was often worse in metals than in ceramics. An example was given of lithium-aluminum alloys, in which the threshold ΔK was only about 1 $MPa\sqrt{m}$, in contrast to the value of some 8 $MPa\sqrt{m}$ mentioned for toughened zirconia.

The discussion then turned to monotonic loading. Some of the issues raised included the following:

1. In composites, different failure mechanisms can occur and fracture toughness can have no meaning, e.g., multiple matrix cracking mechanisms in continuous fiber composites do not give failure by the growth of a single crack. In cases where a single crack does cause failure, this is invariably associated with a crack resistance curve.
2. If the macroscopic stress/strain curve is asymmetric – i.e., nonlinear in tension with a lower yield stress than found in compression (as in toughened zirconia and in some composites) – then stress redistribution can occur in flexural loading making the actual stresses on a component very different from those calculated on the basis of linear elasticity.
3. The implications of crack resistance curves for strength were discussed. The strength is determined by the slope of the resistance curve and not by the steady-state fracture toughness. The strength is damage tolerant because stable crack growth is found for flaws up to a critical point on the crack resistance curve. This can be a very significant effect and very important for the design of materials. An analysis was presented (D.R. Clarke, IBM Yorktown Heights) for the change in Weibull distribution caused by a crack resistance curve which is insufficiently steep to give rise to stable flaw growth. Finally, crack resistance curves may not be strictly considered as material property – i.e., they can be dependent upon the size of the initial crack.

In the end, the discussion came to the perhaps inevitable conclusion that there was no single parameter sufficient for design. Moreover there was no clear minimal target for the value of fracture toughness to which one should aspire, except in that materials needed to be tough and strong. Although in terms of the initial objectives of this session, this was a somewhat sobering note on which to finish, this should not be considered surprising. It would be nice to have a single number for design purposes and for the characterization of a material; however, this is not the case with advanced structural metals and it should not be expected with advanced ceramics.

In looking for the best way forward, it must be recognized that it is necessary to understand different failure mechanisms, crack resistance curves, and fatigue and also to understand the interrelations. Moreover in terms of processing materials for optimum properties, it must not be assumed that properties such as the fatigue limit, strength, and toughness will necessarily scale with one another. Although this makes life more difficult, there is the optimistic conclusion that this way may give us the opportunity to refine the properties of a material more closely for specific applications.

Processing.

R.J. Brook, Max Planck-Institut für Metallforschung, Stuttgart

The session on processing was divided into two parts. The first related to the preparation of toughened components with an approximately equiaxed grain structure. The second related to components in which the toughening phase comprised whiskers, fibers, or other nonequiaxed structures. Emphasis throughout was on the specific problems posed for processing by the preparation of toughened microstructures.

In the opening review, H. Schubert (Max-Planck-Institut für Metallforschung, Stuttgart) discussed the evolutionary progress that had occurred in the fabrication of ceramics. He noted one significant feature of toughness, namely, that it greatly eased the task of the processor in that the resulting damage tolerance reduced the importance of those faults that remained in the processed structure. In discussion of the processing difficulties introduced by whiskers and fibers – i.e., problems with packing, with backstresses, and with shrinkage anisotropy – he described methods which offered promise in terms of providing solutions. The conflict presented by the requirement for densification and for creep resistance at high temperature were treated; most recipes for the enhancement of sintering, such as the presence of liquid phase, brought about accompanying problems with enhanced creep rates. The implications for the design of high-temperature microstructures were underlined.

In a concluding section he noted the need to optimize the properties of powders with regard to a considerable range of variables. Many commercial powders and many powders under development concentrated attention on one of these variables at the expense of the others; this emphasis was not been as a promising line of progress.

In the first of the papers in the section relating to equiaxed grain microstructures, L. Winnubst, (University of Twente, the Netherlands) discussed the preparation of very fine active powders of yttrium-doped tetragonal zirconia polycrystals. Careful preparation of precipitate powders prepared by the chloride route yielded a powder particle size of 8 nm and a fired grain size of 1/10 of a micrometer.

The benefits of atmosphere control were underlined in a paper by Heussner, in which he described the preparation and annealing of cerium oxide tetragonal polycrystals. The toughness of these materials is well known and the objective was to improve the mechanical strength. The best results were achieved by densifying the material, using HIPing under mildly oxidizing conditions. A subsequent anneal in nitrogen chemically reduced the surface layer and formed a zone susceptible to a tetragonal to monoclinic phase transformation on cooling. The resulting surface stresses yielded materials with a strength of 500 MPa. The combination of HIPing and subsequent controlled atmosphere annealing was seen as a promising path for development.

The superplasticity of the zirconia/mullite system was exploited by I.W. Chen (University of Michigan, Ann Arbor) in the preparation of dense components using extrusion. Grain-growth was not encountered during processing and the dependence of the densification rate on the 1/3-power of the grain size suggested process control by grain boundary diffusion. The system was seen as a good model on which to test theories of superplastic deformation.

The use of a reaction during the sintering process was discussed by A. Mocellin (Ecole Polytechnique Féděral de Lausanne) with respect to a variety of chemical systems including oxides, nitrides, and carbides. As an example, the combination of zirconium nitride with titanium oxide to yield zirconium oxide and titanium nitride was quoted. By studying reaction couples formed from sandwiches of predensified plates and by studying the reaction in powder mixtures, it was possible to form some estimate of the rate of reaction and of the suitability of the reaction for the preparation of dense components. The process could be extended to the fabrication of composites by using the chemical reaction to provide the bonding phase around included grains, whiskers, or fibers.

In the final contribution to the section on equiaxed microstructures, Calvert (affiliation not known) underlined the benefits that would arise from step improvements in processing undertaken as a consequence of identified causes of failure. A feature of the specific process sequence described was the combined use of powders and dilute polymers; the codeposition of these two species from the solution led to powders which were suitable for subsequent colloidal pressing.

In the first of the papers relating to the preparation of nonequiaxed toughened microsructures, I. Aksay (University of Washington, Seattle) first underlined the steps to be taken in improving the fluidity of suspensions with high solid contents. The benefits of minimizing the hydrodynamic radius of powders in suspension and of exploiting the particle size distribution were noted. Very fine powders (30 nm) gave trouble with low green densities but the use of surfactants offered promise as a means of improving the packing density. Experiments with gold particles were cited. The packing of whisker composites dependent upon the length-to-diameter ratio of the whiskers; short whiskers offered considerable benefit in terms of the packing densities achieved. The density could also be enhanced by lining up the whiskers in an ordered array using ultrasonic methods. As alternative methods for the preparation of toughened microstructures, the use of inorganic polymer binders and the technique of metallic infilling were described.

The complexities of achieving good suspensions of powder/whisker/sinter additive combinations in aqueous solution were described by P. Greil (TU Hamburg-Harburg, Stuttgart, West Germany). The method used was that of pH-control and good results were achieved up to fiber loading of 15 vol/percent. The extremely anisotropic shrinkage encountered during the sintering of systems in which planar arrays of whiskers had formed was noted. Experiments also suggested that similar fired densities were reached notwithstanding the green density of the formed piece.

Industrial experience with the fabrication of cutting tools formed from composite systems (silicon carbide whiskers in an alumina zirconia matrix) was described by U. Dworak (Feldmühle AG). Faults were found in the as-fabricated pieces as a consequence of the occasional presence of oversize whiskers found in the raw materials. Such large whiskers were focal points for whisker clustering and for porosity in the final sintered piece. A problem encountered with high-speed cutting which led to high temperature in the work piece was also encountered; this was attributed to oxidation of the silicon carbide whiskers in the matrix.

Short Contributions.

"*The Industrial View*", L. Cartz, ONREUR.

The closing session consisted of a group of some dozen short contributions addressing a variety of the themes which had been raised at earlier stages in the meeting. Although the range of topics covered in this closing session was wide, the subjects can be grouped into four categories.

The first group related to attempts to toughen microstructures by the growth or inclusion of a high aspect ratio phase. In the opening remarks R.W. Davidge (UK Atomic Energy Authority, Harwell Laboratory) reported data on composites formed from a pyrex matrix and Nicalon fibers. The behavior was excellent provided that loading was applied parallel to the fiber axis in these oriented fiber structures. A Weibull modulus of 30 and a strength of 1.25 GPa indicated the benefits of such materials; the strength did, however, fall off dramatically as the load was increasingly applied off fiber axis.

Work at Rhone-Poulenc on the fabrication of silicon nitride/silicon carbide fibers was reported by Dr. Chanc-Chine (Rhone-Poulenc, France). The fibers were 15 microns in diameter and had a strength of 2 GPa. They could be prepared in lengths up to 5 km and their corrosion resistance was better than that of rival materials. Present plans were for production at the 20 kg/month level.

A systematic study of the influence of rare earth additives in the sintering of silicon nitride was reported by Peuckert (affiliation not known). The additives were incorporated together with aluminium oxide; the microcstructural behavior in terms of the aspect ratio of the silicon nitride grains was then correlated with the density achieved. Generally, those additives which produced a high aspect ratio such as samarium oxide, where the ratio was 14, led to poor densification behavior. The conclusion was that an aspect ratio of 10 was really a limit beyond which further lengthening brought little benefit. In this regard, gadalinium oxide used in combination with aluminum oxide was a good compromise.

Work at NGK on the fatigue behavior of silicon nitride was reported by Soma. In tests of fatigue at frequencies ranging between 0.03 and 30 kHz, fatigue limits were identified which, in the case of tensile/compressive loading, lay at the level of 50 percent of the original strength. Grain boundary microcracking was identified as a possible cause.

The second group of papers related to alternative methods for achieving toughness. Work with Lanxide was described by Professor N. Claussen (TU Hamburg-Harburg Forschungsschwerpunkt, West Germany) ; the flexibility of this fabrication method which depends upon controlled oxidation of a metal melt was clearly evidenced through the variety of possible microstructures attainable. In particular, examples where the melt was used to infiltrate as matrix phase between particulate or fiber inclusions demonstrated the range of material which could potentially be formed. A benefit with the process was that grain boundaries in the matrix phase were all of a low-angle character. These were free from second phases and therefore offered the potential of relatively good resistance to creep. The continuous metal phase of aluminum itself does, however, limit the upper application temperature.

The value of sandwich structures in which alternate layers of aluminum oxide and of zirconia toughened aluminum oxide were employed, was explained by Boch. The toughness enhancement was clear with values rising from 3.5 to 5.1 MPa$\sqrt{m}$; this was, however, obtained at some cost in strength which fell from 380 to 117 MPa as measured in tension. Analysis of the sandwich structure suggested that it was necessary to avoid excessive interface stresses between the different layers arising from the different thermal expansion coeffecients. The conclusion was therefore that the optimum structure consisted of relatively thick plates (220 μm) bonded together with borosilicate glass. The material had applications in armor.

The third group of papers consisted of contributions relating to test methods. In respect to R-curves, work at Lyon was described by Orange, who had made measurements on magnesium partially stabilized zirconia and had linked the R-curve behavior to tests of acoustic emission. The R-curve behavior itself was surprising in that the slope was negative without any initial identifiable rise. No explanation for the observation had been found.

In a discussion of R-curve behavior, Professor Steinbrech (Universität Dortmund, West Germany) emphasized that the slope found in the R-curve depends on the crack size in components of similar size. In this way, the R-curve is dependent on crack history; this greatly complicates the study of such curves and their use in the interpretation of mechanical property behavior. It was, in particular, important to identify the nature of short surface cracks and the way in which such cracks grew in the microstructure. This need have no relation to the toughness as observed at lone crack lengths (say for long thermal shock cracks) as observed in toughness tests.

A novel procedure for measuring the thermal shock resistance of components intended for high-temperature use was described by G. Schneider, Max-Planck-Institut für Metallforschung. The benefits of the test and its increased validity in comparison with water quench tests were demonstrated by way of results from silicon nitride and silicon carbide components.

The last section in the meeting was taken up by two comments from the industrial sector. The difficulties at the interface between the research scientist and the working industrial engineer were emphasized by Dr. Marmach (Céramique Techniques Demarquest, Trappes, France) in a report of his experience with the exploitation of zirconium oxide materials. The excellent behavior of such material with Weibull modulus values between 32 and 45 and strength values of around 800 MPa had led to increased industrial usage. It was, however, important that, where toughening mechanisms were discussed, as in the present meeting, recognition should be given to the eventual need to translate the progress that had been make into a form that could be recognized by the industrial sector.

A last contribution contained a question relating to the central theme of the meeting. In reviewing the toughening mechanisms which had been explored, W. Clegg (ICI America, Inc., Wilmington, Delaware) noted that none of these would be appropriate for use at high temperature. In view of the need and wish to exploit ceramics under high-temperature conditions, the need for radically different approaches was emphasized.

Required Research Initiatives.

Topics noted for attention in future work are noted below.

A. General

Fatigue. The nature of fatigue mechanisms in ceramics and the prevalence of fatigue for different ceramic systems are little understood and are of major significance for applications. The relative importance of fatigue in toughened ceramic microstructures must be assessed to guide microstructural design for such materials.

High Temperature. In view of the ambition to use ceramics at high temperature, the relative lack of attention to the characterization of microstructures and failure mechanisms at high temperature is a serious omission. The refinement of high-temperature testing and the specific design of microstructures for high-temperature stability and toughness are important research tasks.

B. Research requirements identified under specific sessions

Toughness/Microstructure

R-curves	Agreed geometry for testing Calculation of curves for specific mechanisms
Synergism	Nature of interaction between different toughening mechanisms
Ductile phase toughening	Plasticity of constrained particles Studies of bridging zone behavior Control of particle/matrix interface
Fibers/whiskers	Nature of fiber/matrix debonding Design of interface coatings of suitable stability and bonding
Microcracks	Modeling of toughening behavior Assessment of prevalence of the mechanism

Interfaces/Microstructure

Interface design	Debonding phenomena for fibers and particles Characterization and testing at high temperature

Processing/Microstructure

Densification of composites	Evaluation of limits for pressureless densification and identification of responsible impediments
Whiskers/fibers	Availability of wider range of controlled microstructure reinforcement phases
Fine grain size	Extension of processing capability to finer powder sizes
Reaction sintering	Preparation of required composite microstructures by controlled *in situ* reaction
Alternative methods	Radical alternatives to powder/sinter fabrication

5. Some Exceptional Laboratories of Relevance to Materials Science

There are very many excellent laboratories and research institutes in Europe, involved across the whole spectrum of scientific endeavors. The list which follows is a selection of a few of these laboratories and research activities which are related to work in materials science. They cover a wide range of subjects, and are selected because they are worthy of special attention since they may be of help in the undertaking of research studies in their fields. The list is presented in two parts: laboratory facilities, and research activities. (It must be stressed that this list is incomplete, and can in no way be considered exhaustive.)

The laboratories referenced and described here includes those for:

- Corrosion studies
- Laser beam treatment of surfaces
- Ultraclean ceramics
- Surface analysis
- Thermal plasma technology
- Positron annihilation

The Resea.ch Activities Include:

- Levitation
- Nondestructive testing
- Electron microscopy
- Ultrahigh vacuum systems
- Osprey powder metallurgy processing
- Single-crystal automated orientation (turbine blades)

Corrosion Laboratory of the Petten JRC

The Joint Research Center (JRC) at Petten, set up by the Commission for the European communities (CEC), has developed a special laboratory in a dedicated building for studies of corrosion at high temperatures, under mechanical stresses, and in a range of corrosive atmospheres.

The laboratory is located at the Commission of the European Communities (CEC), Materials Division, Petten Joint Research Centre (JRC) (124, page 17) and is under the direction of M. Van de Voorde, R. Fordham, and J. Norton.

It's experimental facilities include:

- Creep testing machines (about 10)
- Isothermal, or temperature cycling to 1100°C (metals) or 1500°C (ceramics)
- Testing in air, vacuum, Ar, or aggressive gases (C, O, S, halides), in the presence of solid or liquid phases.
- Complicated stress/environment loadings
- Microstructural studies by a wide range of x-ray and electron spectroscopic and microscopic methods.
- Multispecimen autoclaves for long-term experiments in controlled corrosive and/or toxic environments at temperatures up to 1500°C and pressure of 5 bar
- Horizontal tube furnace assembly for the study of corrosive effects of SO_2 at temperatures to 1500°C
- Thermogravimetric apparatus suitable for kinetic and mechanistic studies in highly corrosive environments at temperatures up to 1500°C

Research activities so far have covered corrosion of Si_3N_4 materials by metal oxide and metal salt contaminants; corrosion studies of steels for the petrochemical industry; coal conversion systems; gas turbines; superalloys; steam turbines.

Comment. The Petten corrosion laboratory is well set up as a most useful and practical facility, able to undertake a wide range of corrosion studies. There is much demand for services by European industries.

Laser Beam Treatment of Surfaces

A special laboratory (CTML) for studies of laser treatment of materials was set in June 1985 in the Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland (128, page 18). This laser facility, under the director Professor W. Kurz, is part of the Laser Processing Research Group in the Physical Metallurgy department of EPFL. Extensive research studies are being undertaken jointly with industry.

The experimental facilities consist of a continuous (CW) CO_2 laser, operating in air, of output 100-10^7 W/cm^2, wavelength 10.6 μm, and power 50 W to 1.5 kW. There is a beam-guiding system with numerically controlled high-speed x-y table, permitting treatment of plane surfaces up to 1x1.2 m.

Research activities include:

- Quantitative analysis of rapidly solidified dendritic and eutectic microstructures
- Cladding/remelting of iron and aluminum alloys by laser beam
- Modeling of equiaxed grain growth in metals and alloys
- Coupling of microscopic models with macroscopic heat-flow calculations.
- Analysis of mechanical behavior of as-solidified alloys
- Martensitic hardening
- Surface alloying with particle injection.

Ultraclean Ceramic Laboratories

Several ceramic laboratories are set up to work under ultraclean conditions; two of them are noted here. The ceramics laboratory, at Mol, Belgium, is well developed for the processing of ceramics by a wide range of techniques. Since the earlier work at Mol was concerned with Pu and U compounds, ultraclean conditions were developed to avoid any dust problem. At Stuttgart, the location of the second laboratory, a clean room has been established recently, using semiconductor-type criteria.

The laboratories are located at the: Ceramic Research Department S.C.K./C.E.N., Mol, Belgium (126, page 18) under the direction of A.J. Flipot. The experiment facilities at Mol are:

- Computer controlled graphite resistance furnace
- Thermobalances (1600°C)
- Dilalometers (2000°C, 50 bar, N_2)
- W filament furnace to 2500°C
- HIP system (2000°C, 2 kbar, neutral atmospheres)
- Large-volume sintering furnace (2000°C, 1 mx25 cm, various atmospheres)

The research activities at Mol include the sintering of Si_3N_4, Al_2O_3, Li-silicates, Li-containing ceramics, and U and Pu oxides.

At Stuttgart is the Powder Metallurgy Laboratory Stuttgart (107, page 16), under the direction of Professor G. Petzow. The PML clean room facility comprises a 170 m^2, 5-m high laboratory hall of class 10000 (US Federal Standards), as well as several clean service rooms covering an area of about 100 m^2.

The research activities at Stuttgart are concerned with powder metallurgy, Be single crystals, SiC whisker composites slip casting, non-oxide composites, oxidation and corrosion of ceramics, hard materials (B_4C, SiC-based), AlN, high-purity ceramics, and other studies.

Comment. In both laboratory clean rooms, an excellent team of workers with well-run equipment and highly trained technical staff are available for detailed studies of ceramic processing under ideal conditions.

References 33 and 34, page 41.

Surface Analysis Laboratory

The surface analysis laboratory of the University of Surrey, UK, is a regional research facility for surface analysis established by the Science and Engineering Research Council (SERC), UK. Equipment funds have also been provided by several UK government agencies, including the Ministry of Defence (MOD) and the Royal Aircraft Establishment Farnborough.

The laboratory, located at the Microstructural Studies Unit, University of Surrey (40, page 10), is under the direction of J.F. Watts and J.E. Castle.

The Surface Analysis Laboratory operates four x-ray photoelectron spectroscopy (XPS) systems for chemical analysis of surfaces, together with a scanning Auger microscope (SAM) for surface analysis at high spatial resolution (1000 Å). This instrument is also equipped for both x-ray detection and excitation, so that it is possible to acquire Auger and energy dispersion x-ray system (EDXA) spectra simultaneously, giving the chemical composition of the surfaces and of bulk of the material. The provision of a twin anode x-ray gun enables XPS and low-energy x-ray fluorescence spectroscopy (XRF) using incident x-rays of 12 keV. This is especially useful for providing bulk and surface analyses of insulating materials such as paint films or catalysts.

The research activities of the surface analysis laboratory have covered:

- Surface chemistry of silicon compounds
- Cathodic disbonding of polymeric coatings of steel pipelines
- Film formation on Cu alloy condenser tubing
- Influence of substrate oxide on brazing processes
- Film formation on alloy steels by chelating agents
- Grain boundary segregation and stress corrosion cracking

Reference: 35, page 41.

Thermal Plasma Technology Laboratory

Research and applications of high-temperature plasma in material science and chemical processes are being undertaken in Limoges, France. The laboratory is located at Laboratoire de Thermodynamique et Plasmas, Université de Limoges (65, page 12)

The laboratory director, P. Fauchais, works with A. Catherinot, C. Martin, B. Pateyron, and J.F. Coudert.

The studies undertaken are in the following areas:

- Modeling of plasma flow; interactions with solid particles
- Diagnostics, spectroscopy, laser fluorescence, pyrometry
- Torch and plasma furnace design
- Ceramic and metallic coatings; plasma spray and plasma deposition
- Thermal properties of plasma-spray coatings:

The experimental facilities available include:

- Direct current arc plasma between 5 and 1000 kW using different gases such as argon, helium, nitrogen, hydrogen, air, and water vapor at atmospheric and at reduced pressures
- Low-pressure flowing discharges with pressures varying from 0.02 to 10 Torr.
- Different plasma torches with power capabilities between 5 and 100 kW
- A 1-m^3 vacuum plasma-spraying chamber pressure down to 5 Torr A statistical two-color pyrometer to

measure in flight the surface temperature of the particles, with the data treatment on line by microprocessor

- A laser fluxmeter to follow the mean trajectory of the particles injected into the plasma

References: 36 and 37, page 41.

Positron Annihilation Laboratories

The type of defect near the surface of metals and semiconductors determines the lifetime of positrons, so that measurements of positron lifetimes enable the number and type of defect cluster to be determined. This provides a method of monitoring the very earliest stages of microcrack formation, and so is important in predicting materials failure.

Several university and industrial laboratories are undertaking research and development studies of this type.

- Institut Nationale Science Technologie Nucléaire (I.N.S.T.N.) (93, page14). C. Corbel is the scientist responsible. Extensive and careful laboratory facilities are available with low-temperature, Na^{22} coincidence detectors. Positron lifetimes in defect clusters of various shapes and structures are calculated and compared to experimental data for several Au and other metal alloy systems (see Corbel, C., P. Moser, and M. Stucky, "Positron Lifetimes in Vacancy Type Defects After Electron Irradiation in Metals and Semiconductors," *Annal Chimie Francais*, 10 [1985], 733-749).
- University of East Anglia, UK (41, page 10. Developments in angular correlation spectrometry involving medical cameras are discussed in *New Scientist*, 29 January 1987, pp 40-43.
- Rolls-Royce plc Advanced Projects Department, Bristol; (14, page 7). P.A.E. Stewart is the scientist involved in studies of lubrication effects by positron emission tomography.

Levitation

The levitation of ceramic, glassy, or metallic spheres can be carried out using ultrasonic waves (J. Magill, EITE) or using an air cushion (C. Potard, CENG. This enables studies to be carried out of materials at very high temperatures, above 3000 K, where no container materials are available, and also enables avoiding any contamination arising from the container material.

The two laboratories are:

The European Institute of Transuranium Elements (EITE), 7500 Karlsruhe (112, page 16) and the Laboratoire d'Etude de la Solidification, Grenoble (CENG) (89, 14, page.

The acoustic levitation equipment at EITE is described in *ESNIB* 87-01:61-63 (1987) and *Science Newsbrief* 5-6 (1987). Spheres of UO_2, Pb, H_2O (3 mm in diameter) can be levitated in stable position for hours. Pulse laser heating permits temperatures above 3000 K to be attained.

The air cushion equipment is described in *ESN* 41-5:249:253 (1987) and in J. Garnier and C. Potard, in *Proceedings 6th European Symposium on Material Science and Microgravity Conditions*, ESA SP-256, Feb 1987, 421-425.

Non-Destructive Testing Center

A nondestructive testing center (NDT) has been set up as a national facility in the UK at Harwell, in the earlier atomic energy center, to serve industry, research institutes, and universities. A wide range of NDT methods is available, and newer methods are under development.

The laboratory is located at National Non-Destructive Testing Centre, Harwell Laboratory; (25, page 9).

The manager of the center is Roy Sharpe; other scientists involved are John W. Sheppard, Jack Seymour, Andrew J. Allen, and Peter R. Williams.

Some of the activities undertaken are the following:

Neutron and x-ray radiography –

- Resolution of very fine defects and structures by microfocal enlargement x-radiography
- X-ray fluoroscopy for "real time" inspection (with computer-aided image processing)
- Dynamic radiography evaluation of working machinery (e.g., engines, pumps)
- Neutron radiography for location of hydrogeneous and other light-element materials in metal components (glue and polymers in fine turbine blade cooking tubes)
- Neutron fluoroscopy to study the dynamics of oil flows in engines

Ultrasonic Techniques –

- Defect location and accurate sizing of defects using pulse-echo or time-of-flight diffraction (TOFD) methods
- Thickness gauging of all types, including monitoring of residual metal beneath corrosion product layers or protective coatings
- Design modeling, development, and production of special-purpose piezoelectric transducers
- Noncontacting ultrasonics using electromagnetic (EMAT) transducers and laser sources
- Residual stress monitoring by ultrasonic velocity measurement
- Grain size and microstructure monitoring by ultrasonic attenuation analysis

Laser Technology –

- Vibration monitoring by laser interferometry, e.g., of engines, ultrasonic transducers

- Particle velocity measurement by laser Doppler anemometry

Other techniques employed and under development are positron annihilation, acoustic emission, and pulse video thermography.

References: 38 and 39, page 41.

Electron Microscopy (Oxford)

The Department of Metallurgy and Science of Materials at the University of Oxford (23, page 8) has several very specialized laboratories devoted to the many different aspects of electron optical techniques and their application to studies of materials science. This represents a probably unique assembly of talent and equipment in the fields of electron optical and other microscope techniques.

Sir Peter B. Hirsch, Isaac Wolfson Professor of Metallurgy, is the department director; other scientists include Dr. M.J. Whelan, Dr. B. Derby, Dr. G.D.W. Smith, and Dr. J.B. Pethica. This is a very active research center; approximately 200 papers were published in 1987.

The experimental facilities include:

- Atomic force microscope (AFM)
- Scanning tunnelling microscopy (STM)
- Atom probe (field emission microscopy with time-of-flight mass spectrometer)
- Analytical electron microscopes (AEM)
- Ultrahigh vacuum scanning transmission electron microscope (STEM)
- High-resolution transmission electron microscopes (HREM)
- Electron probe x-ray microanalyser (EPMA)
- High-voltage (transmission) electron microscope (HVEM)
- Acoustic microscopy.

A low-voltage scanning electron microscope (LVSEM) is being developed with the US Army European Research Office.

The research activities are very wide ranging, covering the following subjects:

- Mechanical properties and microstructure of metals and alloys, ceramics, composites, and strong solids
- Structure and properties of interfaces
- Corrosion
- Radiation damage studies
- Metallurgy in archeology.

References: 40 and 41, page 41.

Ultra-High Vacuum Systems

A very successful industrial unit, VG Instruments Group Companies, produces a complete range of high-vacuum instruments, components, and systems for surface analysis, micromachining, and general research activities. The VG group is divided into about 20 independent companies, each developing and marketing a separate vacuum or surface analysis system. The main address of the group of companies is VG Scientific Ltd. (42, page 10).

The experimental facilities and equipments available include:

- All-metal automated ultrahigh-vacuum (UHV) valves
- UHV manipulators
- Laser cutting machines
- Sputter surface cleaning
- Micro machining
- Residual partial pressure gauges
- Photoelectron spectroscopy for chemical analysis (ESCA) systems
- Scanning electron microscopes (SEM)
- Scanning Auger microscopes (SAM)
- Secondary ion mass spectrometers (SIMS)
- Ion-assisted deposition – dynamic recoil mixing systems.

Osprey Powder Metallurgy Processing

The Osprey process is a rapid solidification process involving the gas atomization of a stream of molten metal to form droplets, which deposit on a collector and solidify. Near-net-shape components are produced in one integrated operation. The process takes place in a protective atmosphere, so that oxygen pickup is avoided. The Osprey process was developed in the 1970's by a small research and development company, Osprey Metals Ltd. (43, page 10), which became a part of SANDVIK (Sweden) in 1979. The company acts as a research and development unit, licensing their deposition processes to other companies. R. Gwyn Brooks is the Director and scientists include: A.G. Leatham and J. Coombs.

The experimental facilities are spray forming systems: solid, round preforms are produced by spray-depositing molten alloy onto a rotating, disc-shaped collection. Disc diameter of 100-250 mm, and ban lengths up to 1 m of 150 mm diameter can be produced. Tube preforms are obtained by deposition onto a rotating tubular collection. Stainless steel tubes up to 8 mm long, 100-400 mm o.d., and wall thickness up to 50 mm can be produced.

Deposition processes have been developed for:

- Superalloys 718, and Rene 95
- Al metal-SiC particle composites
- Metal matrix components (MMC) of Al, Li, and SiC
- Stainless steel tubing.

References: 42, 43, and 44, page 41.

Single-Crystal Automated Orientation (Turbine Blades)

An automated system utilizing real-time Laue x-ray diffraction patterns with robotic handling permits orientation measurement of single-crystal turbine blades to be determined to within an accuracy better than 1° in each arc every 35 seconds. This system has been developed at Rolls-Royce, Derby, UK, by Dr. Colin Baxter (13, page 7).

Single-crystal components such as turbine blades, are produced routinely by withdrawal of a mold from the hot zone of a furnace. The single-crystal turbine blades permit higher operating temperatures (+30°C), or extended lifetime. Reliable monitoring of crystal orientation, which directly affects properties is now required at the shop floor level. This is carried out by the automated system called "Single Crystal Orientation Rapid Processing and Interpretation Operation (SCORPIO)." Components are handled throughout by a robot, which locates the blade in the correct alignment in front of the collimated x-ray beam. A Laue x-ray pattern is obtained using W radiation (applied voltage 40-60 kV), and the back reflection x-ray diffraction pattern is registered on a real-time detector, linked directly to a computer, incorporating an image processing system. This gives a sensitivity substantially better than that of a conventional film technique. A calculated pattern is generated on the screen, which can be manipulated automatically to obtain a match with the observed pattern. When a match is obtained the software reduces the results to a series of six characteristic angles, and finally gives a signal for the acceptance or the rejection of the component. Measurements including generation of the x-ray pattern are typically completed in 1 minute, although times as short as 20 seconds may be achieved. The precision of the measurements are: 0.4 in two rotation axes, 0.7 in the third axis.

6. European Societies and Materials Programs

There are a great many European organizations involved in efforts to keep their constituents informed of the present and future activities of relevance to the area of science and technology in which they work. Unfortunately, there is much overlap and duplication of effort, and there is a decided lack of comprehensive, single-source oversight. Hopefully, in time, and as Europe moves toward 1992 – the magic year of European coherence, country with country in a unified effort – the present provincialism of many of the science and technology societies will have been overcome. In any case, the pressure of need and the logic of coherence will inevitably resolve the profussion, if not confusion, of societies.

The following information is offered as a help in the current circumstance for the American materials scientist to find his way to the information he seeks. It contains information about two new materials societies, both of which are a big step forward toward coherence, and a list of acronyms of many of the most important European scientific and technological research programs and organizations.

European Ceramic Society

A most useful development has been the agreement to establish a European Ceramic Society (ECS). Ceramic societies abound in Europe, where every country has one or more organizations concerned with ceramics, glasses, composites, and other materials. To date the only activity on a European scale to bridge the separations has been the "Science of Ceramics" meetings, held every other year and organized by an ad hoc committee of the Association Européene de Céramique. Following discussions during 1987, representatives from the ceramic societies met in Canterbury, UK, and agreed to form ECS. The agreement has been signed so far by France, Italy, West Germany, the Netherlands, Belgium, the UK, and Spain.

The aims of ECS are to:

- Provide a European forum for planning an independent and considerable role for Europe in the scientific and technical world of ceramics.
- Plan, organize, and hold a European Meeting, convened at least biannually, embracing all ceramic materials and technologies and incorporating the Science of Ceramics Meeting.
- Provide long-term planning of conferences and their publication to avoid clashes and duplication of effort, taking into account the activities of the American and Japanese ceramic societies.
- Coordinate and disseminate information on all meetings organized by the national ceramic organizations in Europe.

- Participate in common actions to promote the interests of the ceramic community and to establish links with other materials organizations. It is expected that the actions of the Society would address education, research and industrial matters.

The council of the new society is to be made up of two members, including the president of each of the national societies. The first meeting of the council was held 18 December 1987. The European Ceramic Society is intended to develop a joint, coordinated approach within Europe to all activities involving the science and technology of ceramics, but at the same time preserving the identity of national institutes and societies.

The "1st European Ceramic Society Conference," which will include Science of Ceramics 15, will be held 19-23 June 1989, in Maastricht, the Netherlands. Topics to be covered are:

- Basic science – processing and properties
- Engineering Ceramics – processing and applications of all ceramics primarily used for mechanical reasons
- Electronic ceramics – the materials and fabrication of all ceramics primarily used for electrical, dielectrical, or magnetic purposes and their applications including sensors, actuators, and substrates
- Traditional ceramics – structural clay products, whitewares, refractories, production technology, process control, quality assurance, and properties
- Bioceramics – fabrication and characterization of bioceramics, and clinical and *in vivo* dental and orthopedic applications
- High T_c superconductors.

Further details about ECS can be obtained from the president of the society, Professor R. Metselaar, Secretariat European Ceramic Society, Centre for Technical Ceramics, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, the Netherlands.

A New European Society of Materials

A federation of European societies of materials has recently been established by an agreement signed on 11 December 1987 by the Deutsche Gesellschaft für Metalkunde, The Institute of Metals (UK), and la Société Française de Métallurgie. It is hoped that other European societies of metals, ceramics, and other materials will join the federation.

The objectives of the federation are to:

- Improve the dissemination of information about the scientific meetings of the individual national societies
- Increase the participation in national meetings, including sponsoring European meetings
- Publish simultaneously scientific reviews of metallurgy in German, English, and French
- Hold an annual major European meeting on materials.

Further information can be obtained from these addressees:

La Société Française de Métallurgie, 1-5 (rue Paul Cezanne, 75008 Paris, France. [Secretary General Yves Franchot, Tel: 1-45-63-17-10]).

The Institute of Metals, 1, Carlton House Terrace, London, SW1Y 5DB, UK, Secretary Sir Geoffrey Ford, Tel: 1-839-4071.

Deutsche Gesellschaft für Metalkunde, Adenauer-Allee 21, D-6370 Oberursef 1, West Germany.

The New Federation of Materials Institutes in the U.K

A Federation of Materials Institutes has been formed in London, UK, by the amalgamation of the Institute of Metals, the Institute of Ceramics, and the Plastics and Rubber Institute. The new Federation will be able to cover the entire field of Materials, and it is contemplated that eventually a single Institute of Materials will be formed in the UK.

The Federation will be governed by a council consisting of the Presidents of the founding societies. Further details may be obtained from Sir Geoffrey Ford, the Institute of Metals, 1, Carlton House Terrace, London SW1Y 5DB, UK.

European Programs in Materials Science and Technology

There is a wide range of European programs of collaboration in the fields of science and technology set up by the Commission of the European Communities (CEC). A short list of the acronyms related to Materials Science is given in Table I. This is just a small selection from the more than 500 abbreviations in current use for programs, institutes, societies, and organizations. Not all of these programs have been established by CEC, some notable examples being the European Science Foundation (ESF), European Laboratory for Particle Physics (CERN), European Space Agency (ESA), European Southern Observatory (ESO), and Versailles Agreement on Advanced Materials and Standards (VAMAS).

Table I. Partial List of Acronyms of the European Scientific and Technological Research Programs and Organizations.

BRITE	Basic Research in Industrial Technologies for Europe
CAP	Concerted Action Program
CCFP	Consultative Committee for the Fusion Program
CEAM	Concerted European Action on Magnets
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CERN	European Organization for Nuclear Research
CERT	European Parliament Committee on Energy, Research and Technology

CIT	Committee on Innovation and Technology Transfer
CODEST	Committee for the European Development of Science and Technology
COMETT	Community Action Program for Education and Training for Technology
COST	European Cooperation in the Field of Scientific and Technical Research
CREST	Scientific and Technical Research Committee
CST	Euratom Scientific and Technical Committee
DELTA	Developing European Learning through Technological Advance
DESY	German Electron Synchrotron
DIANE	Direct Information Access Network for Europe
EAEC	European Atomic Energy Community
EARN	European Academic and Research Network
ECSC	European Coal and Steel Community
EDPEC	Energy Demonstration Program of the European Communities
EFTA	European Free Trade Association
EIRMA	European Industrial Research Management Association
EISCAT	European Incoherent Scatter Radar Facility
EJOB	European joint optical bistability project
ERASMUS	European Community Action Scheme for Mobility of University Students
ERS	Earth Resources Satellite
ESA	European Space Agency
ESEP	European Science Exchange Program
ESF	European Science Foundation
ESO	European Southern Observatory
ESPRIT	European Strategic Program for Research and Development in Information Technology
ESRC	European Science Research Councils
ESRF	European Synchrotron Radiation Facility
ESTEC	European Space Research and Technology Center
EURAM	European Research on Advanced Materials
EUREKA	European Research Coordination Agency
EUROMET	European Collaboration on Measurement Standards
FAST	Forecasting and Assessment in Science and Technology
FEICRO	Federation of European Industrial Cooperative Research Organizations
FP	Framework Program
FTSC	Fusion Technology Steering Committee
IRDAC	Industrial Research and Development Advisory Committee
JET	Joint European Torus
JRC	Joint Research Centre
LEP	Large Electron-Positron Collider
MTH	Major Technological Hazards Program
NEA	Nuclear Energy Agency
NET	Next European Torus
RACE	Research and Development in Advanced Communications Technologies in Europe
RAP	Research Action Program
SPRINT	Strategic Program for Innovation and Technology Transfer
STC	Euratom Scientific and Technical Committee
STD	Science and Technology for Development
STIMULATION	European Cooperation Between Laboratories
STOA	European Parliament Office for Scientific and Technological Options Assessment
TDHS	Technological Developments in the Hydrocarbons Sector
VAMAS	Versailles Project on Advanced Materials and Standards

The European countries are engaged in a policy of encouraging cooperation on a pan-European basis in the basic sciences, technology, and all stages leading up to marketing. There is a very wide diversity of programs, many of which would appear to greatly overlap. There has been a tendency for each program to function as a separate entity from all other programs, which of course, leads to a heavy administrating system. Nevertheless, there is a growing common effort to revitalize some of Europe's more traditional industries as well as to develop new technologies.

Further details of these programs are given in references 1-11, page 40. The European countries involved are listed in Table II, where some are members of CEC, others of the European Free Trade Association (EFTA). Yugoslavia is a member of CERN, COST, and ESF. Poland is a members of CERN. Nearly all countries are member of EUREKA, COST, and ESF. In all cases, the programs are planned and designed to encourage or actually require cooperation across the national boundaries of Europe.

Table II. Participation of European countries in the Commission of European Communities (CEC), and European Free Trade Association (EFTA).

	CEC	EFTA
Austria		X
Belgium	X	
Denmark	X	
Finland		X
France	X	
West Germany	X	
Greece	X	
Iceland		X
Ireland	X	
Italy	X	
Luxembourg	X	
Netherlands	X	
Norway		X
Portugal	X	
Spain	X	
Sweden		X
Switzerland		X
UK	X	

Following are some details on a select few of the European programs concerned with materials: BRITE, EURAM, STIMULATION, COST, JRC, and EUREKA.

The BRITE program

The objective of BRITE (Basic Research in Industrial Technologies for Europe) is the introduction of advanced technology into traditional industries, and in particular, "new technologies for manufacturing industries."

The fields covered so far include:

- Research to make materials, components, and complete systems more reliable, less susceptible to wear, and generally slower to deteriorate
- Laser technology as a production tool
- New joining techniques/new approaches to welding; bonding with adhesives
- New testing methods, often computer-based, preferably nondestructive and for use on the production line and in continuous processes
- Application of advanced materials such as polymers, composites, and new materials with special properties (e.g., plastics which conduct electricity)
- Membrane science and technology
- Catalysis and particle technology
- Automated processing and assembly of flexible materials (including new sewing and knitting technologies) leading to the automated manufacture of, for example, clothing and shoes.

The first BRITE program covered the years 1985-1988, when about 100 projects were funded. Announcement of the second round of BRITE projects is expected in late 1988.

BRITE projects cover a wide range of industrial activities. Some projects are:

- Plasma reactor for surface deposition of corrosion-resistant layers
- SiC-reinforced composite turbine wheel with mechanical strength stability at high temperature
- Self-propelled arc-welding vehicles
- Zeolite crystal catalysts in petroleum refining.

Contacts for further BRITE information are:

Commission of the European Communities
Directorate General for Science Research and Development
Division XII-C-1 BRITE (ArtsLux 3/52)
Rue de la Loi 200
B-1049 Brussels
or:
Mr. G.A. Gadge (UK Representative)
Department of Trade and Industry
RTP Division, Room 206, Ashdown House
123 Victoria Street
London SW1E 6RB, UK.

(See also references 1, [section 16], 9 and 11, page 40.)

Advanced Materials: the EURAM Program

The objective of the research program on materials is to improve management of raw materials by: (1) developing high-quality and cost-effective advanced materials; (2) increasing self-sufficiency in raw materials, both renewable (wood) and nonrenewable; and (3) enhancing capability in recycling and using waste materials.

European Research on Advanced Materials Program (EURAM) is concerned with advanced materials, and the commitment to EURAM is expected to increase during the current research period, 1987-1991. The fields of study covered in the program for 1986-1989 covered:

- Primary raw materials
- Secondary raw material – (1) recycling of nonferrous metals and (2) recycling and utilization of waste
- Wood as a renewable raw material
- Advanced materials (EURAM).

The topics covered by EURAM include the development of advanced composites, ceramics, polymers, superalloys, fibers, amorphous materials and biomaterials. Some specific studies concern:

- Ceramics intended for future generations of internal combustion engines, especially the adiabatic diesel engine operating at a constant temperature of 1500°
- Composite materials; synthetic resins with carbon or glass fibers; metal matrix composites
- Mechanical properties and corrosion resistance properties of steels, alloys, and engineering ceramics
- Data bank of characteristics of high-temperature materials
- Processing of monolithic ceramics SiC, Si_3N_4, ZrO_2, Al_2O_3: whisker/fiber composites
- Studies of Al, Mg, and Ti alloys.

Contacts for further information are:

Mr. A. Garcia Arroyo
Commission of the European Communities
Directorate-General XII-G
rue de la Loi 200-B-1049
Brussels, Belgium

or:

M. Wurm, Matériaux Avances
(European Research on Advanced Materials) (EURAM)
Commission of the Communities (CEC)
rue de la Loi-200-B-1049
Brussels Belgium.

(See also references 1 [section 17], 9, and 11, page 40.)

STIMULATION

The objective of the STIMULATION program is to aggressively encourage European cooperation between laboratories in different European countries. The support available under STIMULATION is for personal mobility and for the twinning of research teams from at least two European countries.

Examples of corporations are:

- Concerted European Action on Magnets (CEAM); focuses on Fe-rich, rare earth magnetic materials such as $Fe_{20}Nd_{18}B_2$
- Microionic solid-state batteries, based on a Si chip

- High-molecular-weight polymer liquids, and their liquid-solid transition under tension
- Catalytic properties of materials.

Further information can be obtained from: L. Bellewin

Commission of the European Community
Stimulation Action
Directorate General XII-H
Rue de la Loi 200
B-1049 Brussels
(See also reference 11, page 40.)

COST

European Cooperation in the Field of Scientific and Technical Research (COST) has existed since 1971, as an informal organization to promote European collaboration in research and development. There are 19 participating countries: the 12 CEC countries, with Austria, Finland, Norway, Sweden, Switzerland, Turkey, and Yugoslavia. Metallurgy and materials are among the projects being undertaken.

Further information can be obtained from:

COST Secretariat
Secretariat General of the
Council of the European Communities
Rue de la Loi 170
B-1048 Brussels
(See also reference 1 [sections 1.1 and 38] page 40.)

Joint Research Center (JRC)

Research studies are funded by the CEC at four JRC's. These in-house programs are known as "direct-action, and are located at four locations – the Ispra Establishment (Italy), the Central Bureau for Nuclear Measurements at Geel (Belgium), the Institute for Transuranium Elements at Karlsruhe (Germany), and the Petten Establishment (the Netherlands). The work is focused on four main themes, one of which is advanced materials and testing.

The work is distributed among the four locations as follows:

JRC Geel (127, page 18)

JRC Ispra, (specialized laboratories in electronics, materials science, radiochemistry, and ion foundry (120, page 17).

JRC Karlsruhe (ceramics research in the nuclear field [112, page 16, and Levitation, page 33)

JRC Petten, (high-temperature materials laboratory [124, page 17, and Corrosion Laboratory, page 31])

The work on engineering ceramics at JRC are reviewed in references 7 and 8, page 40. Further information can be obtained from:

Commission of the European Communities
Joint Research Centre
Director General
rue de la Loi, 200
B-1049 Brussels, Belgium.
(See also reference 1 [sections 1.1 and 39] page 40.)

EUREKA

The European Research Coordination Agency (EUREKA) was established in 1985 to stimulate collaborative research in commercially important technologies. This is a pan-European program for the exploitation of research. There are 18 member countries (as in Table II, but with the addition of Turkey, but exclusion of Iceland). EUREKA projects are market-led. Their aim is to produce internationally competitive high-technology products, processes, and services, using the European market as a springboard. EUREKA is complementary to the research and development programs, which concentrate more on precompetitive research. The fields of work under EUREKA are wide ranging, they include: electronics, materials, and lasers.

Some examples of developments EUREKA projects focused on are:

- Car structures using new materials
- Automatic integrated system for neutron-radiography
- Superconducting wire and magnets for very high field applications
- Precursors for high-performance ceramics by wet chemicals
- Coatings for advanced technology.

Further information can be obtained from:
R. Meijer, Eureles
Secretariat, BP 69, B-1000
Brussels 23, Belgium.
(See also reference 1 [section 42], page 40.)

7. References and Bibliography for the Source Notes to Materials Research Activities in Europe

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2. *Update, Newcastle-upon-Tyne Polytechnic Products Ltd*, Library Building, Ellison Place, Newcastle-upon-Tyne NE1 8ST, UK.

3. *Interface Europe*, c/o Institute of European Trade and Technology (IETT), 64 West Smithfield, London EC1A 9EH, UK.

4. EUROTEC, Commission of the European Communities, DGX (Information, Communication and Culture), Rue de la Loi 200, B-1049 Brussels, Belgium.

5. Budd, S.A., *The European Economic Community (EEC): A Guide to the Maze*, published by Kogan Page Ltd, UK.

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29. Van der Voorde, M., "Environmental Effect on the Damage of High Temperature Materials," *Materials Science and Engineering*, 88 (1987), 341-346.

30. "Engineering Ceramics at the European Research Centre, Petten," *ESNIB* 88-03: 57-59 (1988).

31. Dekumbis, R., "Surface Treatment of Materials by Lasers," *Chemical Engineering Progress*, (December 1987), 23-29.

32. "Materials Research in Lausanne, Switzerland," *ESNIB* 88-04:26, 28 (1988).

33. "Ceramics Research at the Nuclear Research Establishment, Mol, Belgium," *ESN* 87-01:64-65 (1987).

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36. "Plasma Spraying of Ceramic Coatings," *ESNIB* 87-01:30 (1987).

37. Tronche, A. and P. Fauchais, "Hard Coatings (CrO_3, WC-Co) Properties on Al or steel Substrate," *Materials Science and Engineering*, 92 (1987), 133-144.

38. "Non-Destructive Testing Center, Harwell, UK." *ESN* 41-7:402-404 (1987).

39. *The NDT Yearbook 1987/88*, published by The British Institute of Non-Destructive Testing, 1 Spencer Parade, Northampton NN1 5AA, England, Tel: (0604) 30124, Telex: 31612 OTSSG.

40. "Atomic Scale Microscopy at Oxford, UK," *Science Newsbrief*, 6-3 (1988).

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42. "Osprey Breaks New Ground in Spray Deposition Technology," *MPR*, October 1987, 712-716.

43. "Powder Metallurgy Meeting in Switzerland," *ESNIB* 88-02:44-47 (1988).

44. Fiedler, H.C., T.F. Sawyer, R.W. Kopp, and A.G. Leatham, "The Spray Forming of Superalloys," *Journal of Metals*, 39 (1987), 28-33.

45. "Composite Materials Conference in France," *ESN* 41-10:555 (1987).

46. "Broussand, D., Engineering Ceramics Activity in France," *L'Industri Ceramique*, No. 809 (1986), 645-648.

8. Materials Meetings in Europe

Several conferences on materials are to be held in Europe from April 1989 through September 1990. Those meetings are listed below as announced to date (and of which I have knowledge). Further details can be obtained from the relevant organization.

3-6 Apr 1989	Surrey, England	Low Energy Ion Beams	Institute of Physics 47, Belgrave Square London SW1X 8QX England
4-7 Apr 1989	London, England	Annual Congress, Royal Society of Chemistry	Dr. J.F. Gibson The Royal Society of Chemists Burlingon House London W1V 0BN England
5-8 Apr 1989	Oxford, England	British Crystallographic Association Spring Meeting	Dr. J.M. Squire (BCA) Biophysics Section Blackett Laboratory Imperial College London SW7 2BZ England
26-28 Apr 1989	Bad Nauheim, West Germany	3rd Int'l Conference on Joining of Ceramics, Glass, and Metal	Deutsch Gesellschaft für Metallkunde e.V.m Adenauerallee 21, D-6370 Oberursel West Germany

May 1989	Saint Etienne, France	26th Special Steels Conference	Cercle D'Etudes des Métaux 158, Cours Fauriel 42023 Saint-Etienne Cédex France
4-9 Jun 1989	London, England	ITSC '89 - 12th International Thermal Spraying-Conference	The Welding Institute Abington Hall Abington, Cambridge CB1 6AL England
16-17 Jun 1989	St. Etienne, France	Mechanical Characteristics of Composites	Alain Vautrin Ecole des Mines 158, Cours Fauriel France
19-23 Jun 1989	Maastricht the Netherlands	1st European Ceramic Conference including Science of Ceramics 15	
26-29 Jun 1989	Jerusalem, Israel	Composite Materials for High Temperatures	Ms. Shulamit Cahana National Council for R&D Ministry for Science and Technology Hakirya Hamizrachit Jerusalem Israel
2-7 Jul 1989	Leningrad, USSR	Interantional Congress on Glass	Secretariat of the XV Int'l Congress on Glass I.V. Grebenshchikov Institute of Silicate Chemistry Academy of Sciences of the USSR ul. Odoevskogo, 24 kor. 2 Leningrad, 199057 USSR
17-21 Jul 1989	Paris, France	3rd International Symposium on Acoustic Emission from Composite Materials. AECM 3	Daniel Valentin Ecole des Mines de Paris Centre des Materiaux BP 87 91003 EVRY Cedex France
24-26 Jul 1989	Paisley, Ecosse, Scotland	The 5th International Conference on Composite Structures (ICCS-5)	Dr. I.H. Marshall Department of Mechanical and Production Engineering Paisley College of Technology High Street Paisley PA1 2BE Scotland

4-8 Sep 1989	Herceg Novi, Yugoslavia	18h Quadrennial World Round Table Conference of Sintering	Dragan Uskokovic Serbian Academy of Sciences/Arts Institute of Technical Sciences Box 745, 11001 Belgrade Yugoslavia
10-12 Apr 1990	Warwick, England	New Materials and Their Applications	Dr. S.G. Burnay Harwell Laboratory Didcot, Oxon OX11 0RA England
Jul 1990	Bordeaux, France	16th General Assembly and Int'l Congress Int'l Union Crystallography	Professor M. Hospital Lab de Cristallographie Université de Bordeaux 1 351 cours de la Liberation 33405 Talence France
24-27 Sep 1990	St. Helier, Jersey	European Gallium Arsenide Conference	The Meetings Officer The Institute of Physics 47 Belgrave Square London SW1X 8QX England

Appendix A. Index of ONREUR Publications in Materials Science, 1985 to the Present

The list which follows includes all articles and reports in materials science published by ONREUR (formerly ONRL) since January 1985. In the list below the references in brackets are, for *ESN* articles, to volume, issue number, and page number; thus, [39-1:13] indicates *ESN* volume 39, issue number 1, page 13. References to *ESNIB* articles refer to year, issue number, and page number; thus, [87-01:22] indicates 1987, issue number 1, page 22.

ESN Articles, 1985

Marine Corrosion and Fouling, Kenneth D. Challenger and E.C. Haderlie [39-1:13]

The Sixth International Congress on Marine Corrosion and Fouling featured some first-rate research from Italy on fouling and corrosion, from Greece on corrosion contonol and protection, and from the UK on attachment mechanisms for fouling organisms.

Materials Research in Some Italian Industries, Kenneth D. Challenger [39-1:16]

FIAT's Central Research Laboratory, CISE (the research laboratory of the Italian Electricity Board), and the Italian Welding Institute are doing some very good materials research that is worthy of the US Navy's attention.

Stainless Steels/84 Highlights New Duplex Steels, A.J. Sedriks [39-1:19]

The conference Stainless Steels/84, held in Gothenburg, Sweden, dealth with the scientific and technical advances in stainless steels and their applilcations in the energy industry. Much research and development has gone into the new duplex stainless steels.

Developments in the Techniques and Tools for Microanalysis of Materials at the University of Oxford, Kenneth D. Challenger [39-2:53]
The Department of Metallurgy and Science of Materials at Oxford is doing innovative work on tools and tech-

niques for microanalysis. There have been developments in several areas recently: high-resolution electron microscopy, scanning transmission electron microscopy, acoustic microscopy, low-voltage scanning electron microscopy, digital image processing, and atom-probe microanalysis.

Superconducting Materials, Electrodeposition, and Fracture Mechanics Research in Northern Italy, Kenneth D. Challenger [39-2:57]

Research at the Politecnico di Milano, the Politechnico di Torino, and the Institute for the Study of Non-Traditional Materials is a good mix of fundamental and applied work. The investigators seem to have very close ties with local industry; thus their fundamental research is focused on topics which will support the long-term needs of these industries.

Materials-Science Research Under Microgravity Conditions, Kenneth D. Challenger [39-3:90]

Results of materials-science experiments on Spacelab 1 were reported at the Fifth European Symposium on Material Sciences Under Microgravity. The findings have provided fundamental information on scientific mechanisms which should result in the production of new and better materials.

Gas Turbine Technology Featured at UK Conferences, R.L. Jones [39-4:147]

The conference Protective Coating Systems for High Temperature Gas Turbine Components included papers on pulsed pressure aluminizing, corrosion resistance, and thermal barrier coatings. The UK-US Navy Workshop on Gas Turbine Materials in a Marine Environment focused on the corrosion of hot turbine blades caused by sea salt and fuel impurities.

Welding Research at Aachen University, Kenneth D. Challenger [39-4:149]

Aachen University has two institutes for welding research and development. Prozesssteuerung in der Schweisstechnik focuses on problems associated with the applications of robotics to welding. Institut fur Schweisstechnische Fertigungsverfahren has many research programs covering most aspects of welding.

Materials Testing at West Germany's EHW and MPA Institutes, Kenneth D. Challenger [39-4:152]

The Institute for Ferrous Metallurgy (EHW) at the University of Aachen and the State Institute for Materials Testing (MPA) at the University of Stuttgart are two of the largest organizations in West Germany doing research on the mechanical/fracture properties of structural metals. EHW is involved in all phases of ferrous metallurgy, with emphasis on mechanical/fracture properties, whereas MPA's programs are practically all in materials testing, structural analysis, and materials qualification.

Lulea University – A Hot Spot for Materials Research in the Frozen North, Kenneth D. Challenger [39-5:193]

The Materials Engineering Department of Sweden's Lulea University of Technology is at the forefront of research in certain areas of materials science. This article highlights work on structural ceramics, dual phase steels, hot isostatic pressing maps, welding maps, laser hardening of steel surfaces, and the stability of precipitates in microalloyed steel.

The Welding Institute, UK, Kenneth D. Challenger [39-6:255]

The Welding Institute is probably the best organization of its kind in the free world. It is a center for professional qualification, practical training and education, research, and support to the UK industries involved in fusion welding and other joining techniques. This article surveys the work of the institute's Research Division, Sheet and Precision Processes Division, and Materials Division.

Welding Research at SINTEF, Kenneth D. Challenger [39-6:261]

The welding research at the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) is more fundamental than most welding research in Europe. Nonetheless, it is guided by industrial needs. This article examines research on hyperbaric welding, the implant test, and weld-metal chemistry.

Swedish Institute for Metals Research, Kenneth D. Challenger [39-7:322]

The Swedish Institute for Metals Research, Stockholm, provides R&D support for steel industries in Sweden and all of Scandinavia. This article discusses work in the institute's four departments: Analytical Chemistry, Mechanical Metallurgy, Structural Metallurgy, and Casting and Powder Metallurgy.

The Technion – Israel's Premier Materials-Research Facility, Kenneth D. Challenger [39-7:326]

The Technion, Israel's only institute of technology, is the country's center for materials-related research. This article highlights research on cold sintering, ceramics, rapid solidification, surface modifications and coatings, metal hydrides, and interfaces in solids.

Modern Optics, Microelectronics, and Thin Films Research at Madrid, Paul Roman [39-7:335]

Closely related areas of research in modern optics, solid-state physics, thin films, and microelectronics at three universities and two government research institutes in Madrid are surveyed and assessed. Topics covered include optical bistability, fiber research, gas lasers, nonlinear optical materials and phenomena, crystal growing, laser instabilities, thin film preparation/modification, electron beam stimulated oxidation, and molecular beam epitaxy.

The Soete Institute for Strength of Materials and Welding Technology, University of Ghent, Belgium, Kenneth D. Challenger [39-8:375]

The Soete Institute is the center for materials testing and welding development in Belgium. This article examines work on strain measurement, weldability, and fracture mechanics.

Fiber Reinforced Composite Materials: DFVLR's Institute for Structural Mechanics, Kenneth D. Challenger [39-9:423]

Research at West Germany's Institute for Structural Mechanics is leading toward an understanding of how the various mechanisms of damage in carbon fiber reinforced plastics (CFRP) contribute to the total state of damage and how this damage accumulates and influences the final structure. This article focuses on work dealing with CFRP in structures to be used in space and on research on damage mechanics.

Metallwerk Plansee – A Leader in Powder Metallurgy, Kenneth D. Challenger [39-10:466]

This is the first of two articles this month focusing on the activities of Austria's Metallwerk Plansee. One of the largest privately owned companies in Europe, Plansee is a world leader in research on powder metallurgy.

Plansee Seminar – Progress in Powder Metallurgy, Kenneth D. Challenger [39-10:467]

The 11th International Plansee Seminar was held from 20 through 24 May in Reutee, Austria. This article discusses presentations on refractory metals, coating methods, and hard metals.

Electrodeposition Phenomena in Molten Salts, Kurt H. Stern [39-11:503]

A workshop on electrodeposition phenomena in molten salts was held in London on 8 and 9 July. The workshop covered areas such as fundamental electrochemical studies, lowering of plating temperature, chromium coatings, and electroplating of refractory compounds from molten fluorides.

Microorganism Involvement in Corrosion of Metals in the Marine Environment – Some UK Research, C.P. Patrick Reid [39-11:506]

This article examines the current directions of UK research on biological involvement in the corrosion of metals.

Research at DFVLR's Institute for Metal Research, Kenneth D. Challenger [39-11:510]

The German Aerospace Research Establishment's (DFVLR) Institute for Metals Research (IMR) will play a critical role in West Germany's new 10-year program of advanced materials research to begin in 1986. This article discusses IMR's research on composite materials, metal-matrix composites, high strength Al-Li alloys, ceramics, powder metallurgy Al and Ti alloys, high temperature materials, and spectrum fatigue.

The Spanish Institute for Ceramics and Glass Research, Kenneth D. Challenger [39-11:514]

The Instituto de Cermica Vidro (ICV) is Spain's only research center for ceramics and glass. ICV does state-of-the-art research in phase diagram determinations, tough engineering ceramics, and materials for oxygen sensors.

Fatigue Research at the University of Vienna, Kenneth D. Challenger [39-12:558]

The fatigue behavior of short cracks (less than 0.5 mm) is of worldwide interest because the parameters that influence their rate of propagation and the mechanism of their propagation are not understood. Researchers at the University of Vienna are doing an outstanding job of performing the very tedious experiments required to understand this phenomenon, and they are doing fundamental investigations on the effects of testing frequency on fatigue.

ESN Articles, 1986

Automation and Robotization in the Welding Industry, Kenneth D. Challenger [40-1:18]

Professor F. Eichhorn of Technischen Hochschule Aachen has analyzed the problems associated with robotization of industry and the possible side effects of robotization. This article summarizes a lecture presented by Eichhorn last September during the annual assembly of the International Institution of Welding.

The 3rd International Conference on Composite Structures: Paisley College of Technology, Kenneth D. Challenger [40-1:21]

The Third International Conference on Composite Structures was held last September at Paisley College of Technology, Scotland. This article highlights presentations on the developments of materials, testing methods, and analytical codes.

Conference on Formation of Semiconductor Interface, See-Chen Ying [40-1:30]

Fiber Composite Research at Paisley College of Technology, Paisley, Scotland, Kenneth D. Challenger [40-2:54]

Paisley College of Technology, Scotland, has a rapidly growing program in fiber-reinforced composites. Researchers here are particularly interested in assessing impact damage of composite structures.

International Research on the Physical Metallurgy of Welding: A Review, Kenneth D. Challenger [40-2:55]

New developments in the field, as well as progress reports of ongoing research were presented at the annual meeting of the International Institute of Welding. Commission IX of the Institute is responsible for welding research that is associated with the behavior of metals subjected to welding. The documents arising from this commission's work include official definition of terminology, weld metal hydrogen cracking, and assessment of the state of the art of reheat cracking in steel welds; these documents and progress reports are highlighted here.

Physical Metallurgy Research – An Emphasis on Silicon Metallurgy at the Helsinki Technical University, Kenneth D. Challenger [40-2:59]

Many research projects are in progress at Finland's primary metallurgical research center, including projects in semiconductor metallurgy, superconducting materials, and computer-aided alloy developments.

Ecole des Mine de Paris – France's Premier Academic Center for Materials Research, Kenneth D. Challenger [40-3:95]

Research at the Ecole des Mine de Paris is very closely related to France's industrial needs, but important fundamental, as well as applied, research is being done there – work that US researchers would find beneficial.

Ceramic Matrix Composites, Kenneth D. Challenger [40-4:130]

The fracture of brittle matrix composites was the topic of EUROMECH 204 held in Jablonna, Poland. The papers on composite ceramics and metal-to-ceramic bonding are reviewed in this article.

Fracture Research at the Fraunhofer-Gesellschaft fur Werkstoffmechanik, Kenneth D. Challenger [40-5:157]

The Fraunhofer Institute for Material Mechanics is doing work in fracture mechanics, cold compaction of powder materials, elastic-plastic fracture mechanics, and application of fracture mechanics principles to cutting brittle materials. This article highlights research projects from these areas that are relevant to US Navy needs.

Institut de Soudre: The French Welding Institute, Kenneth D. Challenger [40-5:162]

Most of the research at the Institute de Soudre is applied research and is often focused on solving immediate problems in the field. Topics under investigation are limited to the offshore, transportation, and aviation industries. Many of their research programs are of interest to the US Navy.

Composite Materials Research in Two French Universities, Kenneth D. Challenger [40-6:201]

This article completes ESN's review of the major composite research programs in French Universities. Surveyed here is the single-fiber and fiber-reinforced plastics work at the Centre des Materiaux and the caron-fiber-reinforced plastics (CFRP) research at the Universite de Technologie de Compiegne. With the capability of preforming 3-dimensional weaving with CFRP fibers and the ability to produce carbon fibers, France has become a formidable competitor in composite materials.

Fracture Mechanics and Welding Research at the Technical Research Center of Finland, Kenneth D. Challenger [40-6:203]

Finland's technology for welding materials for use in arctic conditions is very advanced. This survey of the research by the Technical Research Center of Finland covers welding procedure development, weldability, mechanical properties of weldments, fracture mechanics, and fracture toughness and fatigue. Most of their activities are relevant to US Navy programs and the author believes the time is right for developing collaborative research programs with this research center.

Charge-Density Wave Studies in Natural Low-Dimensional Materials at Bristol University, Paul Roman [40-6:207]

Natural quasi-low-dimensional "metals" are studied at the Physics Department of Bristol University. In particular, startling electrical conductivity phenomena are investigated. This article highlights especially nonohmic conduction in steady fields, electrical hysteresis, and an "overshoot" memory effect.

Ion Beam Modification of Materials, IBMM 86, Louis Cartz [40-11/12:425]

Topics at the IBMM 86 conference included ion implantation in semiconductors, insulators, ceramics, and metals. There were also sessions concerning energy deposition and ion ranges, ion beam mixing, reactive ion etching, and amorphization by ion beams. This article focuses on papers dealing with surface microstructure, ion beam mixing reactions, enhanced adhesion, and ion projection lithography.

Tribology Research at the Metal Research Institute of TNO, Irwin L. Singer [40-11/12:429]

Tribological research at TNO's research in failure mechanisms, application of lubricants, application to coatings, and friction and wear behavior of polymeric materials are covered in this article.

ESN/ESNIB Articles, 1987

International Symposium on High-Temperature Corrosion, Robert L. Jones [41-1:10]

High-temperature corrosion of materials and coatings for energy systems and turboengines were the concerns of this symposium, held in Marseilles, France, in July 1986. Topics covered in this article include gaseous oxidations, growth and adherence of protective oxidescales, corrosion by molten salts, ceramics corrosion performance, and coating technology.

Research at Plessey (Caswell) on Materials for Pyroelectric Detectors, Robert Vest [41-2:78]

If the present rate of progress in hybrid pyroelectric/silicon arrays for thermal imaging is maintained, these arrays should in the future be challenging cooled photon detectors for the most demanding requirements. This article surveys the research at Plessey and concludes that Plessey could well be one of the leaders when--and if--the promise of these arrays is realized.

Tribology Research at Laboratoire de Technologie des Surfaces, Irwin L. Singer [41-2:82]

This article covers the laboratory's work in composition, structure, and mechanical behavior of tribological films formed during lubricated sliding, and the surface mechanical properties and wear behavior of ceramics and hard coatings.

NATO Workshop on the Design, Activation, and Transformation of Organo-metallics into Common and Exotic Materials, Robert W. Vest [41-3:129]

The objective of this workshop held in September 1986 in France was to identify the scope and potential rewards of research in development of methods for transforming organometallic compounds into useful materials using chemical vapor deposition, sol-gel processing, or preceramic polymers. Presentations of special interest are summarized.

Some Observations on Research in Poland on Materials for Thick-Film Hybrid Microelectronics, Robert W. Vest [41-3:133]

Polish research in thick-film science and technology at three universities is reviewed in some detail, and the author identifies some excellent work in progress. He concludes that though the state of their research is still behind that of the US, joint research programs with the Poles could be beneficial to the advancement of the science of thick-film hybrids.

A Mass Meeting of Semiconductor Scientists Held in Stockholm, Paul Roman [41-3:143]

A personalized, very selective review of the 18th International Conference on the Physics of Semiconductors is given. Some of the festive plenary talks are mentioned; research on heterostructures and heterojunctions is discussed at some length. Optical bistability and novel far infrared semiconductor laser research is described.

Microstructure Experts Had a Fine Working Conference at Göteborg, Paul Roman [41-3:148]

The 2nd International Conference on Superlattices, Microstructures, and Microdevices was a properly sized, active, working meeting of highly specialized experts. This article reviews selected presentations only in the areas of general properties of quantum structures, magneto-optical studies, microdevice fabrication; it also gives a rather complete description of a panel discussion.

The 8th International Conference on Crystal Growth, Louis Cartz [41-3:154]

Microelectronics at the University of Edinburgh, Robert W. Vest [41-4:192]

This article reviews microelectronics research at the university's Department of Electrical Engineering. While most of the research is related to silicon technology, it is addressed, in particular, to fundamental problems relevant to the future development of silicon-based microelectronics.

THERMOSALT: A Thermodynamic Data Bank of Molten Salt Mixtures, M. Gaune-Escard [41-4:207]

A New European Journal on Semiconductors, Paul Roman [41-4:211]

Crystal Growth Under Microgravity Conditions, Louis Cartz [41-5:249]

The growth of crystals from solution under gravity and microgravity is reviewed. Turbulent convection currents affect crystalline perfection. Methods to reduce convection currents involve using isodensity systems, increasing the viscosity, using special configurational arrangements, or microgravity. Some alloy systems such as Mn-Bi and

Ga-Hg have miscibility gaps which can give rise to macrosegragation effects under gravity. These effects can be overcome under microgravity conditions.

The French Society of Metallurgy, Louis Cartz [41-5:253]

Subjects discussed at the meeting of the Societe Francaise de Metallurgie included quasi-crystalline solids and ion bean mixing. An extensive review is given of the treatment of metals by high-energy beams of ions, lasers, and electronics, when surfaces can undergo structural modifications or changes in composition resulting in modified surface properties.

ONR Branch Office London Sponsors a Session on Interfacial Phenomena in Microelectronics, Paul Roman [41-5:259]

Four talks presented at a special session on interfacial phenomena in microelectronics are reviewed. This session was organized within the framework of a Europhysics Summer School on Physicochemical Hydrodynamics and Liquid State Conference at Rabida, Spain, July 1986. Theory of solidification, layered semiconductor structures, and crystal growth under microgravity were the topics of these ONRL-sponsored presentations.

A Passive Preprogramed Memory Using Thick-Film Technology, Robert W. Vest [41-5:269]

Metal Surface Treatment, Studies at Centre de Recherches d'Unieux in France, Louis Cartz [41-5:271]

UK Heats Up Gallium Arsenide Fires, C.J. Fox [41-5:273]

International Conference on Anomalous Rare Earths and Actinides, Alan S. Edelstein [41-5:280]

High-Temperature Alloys for Gas Turbines and Other Applications, Dasara V. Rathnamma, S.R.J. Saunders, and T.B. Gibbons [41-6:312]

The major topics of this third COST 50/501 conference on high-temperature materials were developments in materials and processing, environmental effects and processing, and mechanical properties and engineering design. The material presented under each of these topics is discussed.

Computer Aided Engineering for Surface Mount Technology in the UK, Robert W. Vest [41-6:314]

The use of computer aided engineering (CAE) for surface mount assembly of hybrid circuits is a promising and rapidly growing area of technology in the UK. This article reviews the presentations on this subject given at a UK colloquium in London in December 1986. The presentations discussed the present availability of CAE tools, the extent of their practical applications, and problems which arise during CAE activities.

Surface Analysis Laboratory, University of Surrey, UK, Louis Cartz [41-6:336]

Materials Analysis for Electronic Devices: A UK Meeting, Louis Cartz [41-7:377]

Several electron spectroscopic and optical techniques are described and their use in qualitative, quantiative, and spatial examination of electronic devices discussed. The methods include laser microprobe and laser scan mass spectrometry, pulsed laser atom probe, x-ray photoelectron spectroscopy, Auger electron spectroscopy, and ion beam crystallography.

A Large Gathering of Solid-State Physicists, Paul Roman [41-7:398]

The 23rd annual Solid Physics Conference of the UK is reviewed. Some special presentations given in plenary sessions are described in some detail. They include a review by Sir Nevill Mott, a talk by 1986 Nobel Laureate Rohrer, and the Simon Prize Lecture by Professor Ym. V. Sharvin.

A Small European Working-Conference on Amorphous Semiconductors, Paul Roman [41-7:400]

The annual Chelsea Conference on Amorphous and Liquid Semiconductors took place in London, 15 through 17 December 1986. This article focuses on general studies concerning amorphous (a)-Si, specific works on a-Si:H, a-As-S, a-As_2Se_3, and conducting polymers.

Nondestructive Testing Center, Harwell, UK, Louis Cartz [41-7:402]

Progress in the UK Low-dimensional Structures Initiative, Paul Roman [41-7:406]

Electronic Ceramics Research at Three Israeli Universities, Robert W. Vest [41-8:425]

A selection of some of the research in electronic ceramics at the Hebrew University of Jerusalem, Technion-Israel Institute of Technology, and Tel-Aviv University is reviewed. The work at these institutions is judged to be of high quality, and the many scientists there are addressing important problems in electronic ceramics.

Research on Advanced Ceramics and Gas Sensors at Harwell, Robert W. Vest [41-8:427]

The emphasis of this report on the Harwell Laboratory of the UK Atomic Energy Authority is on the R&D work in semiconductor gas sensors. The author concludes that the Harwell people are demonstrating that basic research, applied research, and device development are not incompatible endeavors and that all three benefit from the interactions generated within the same group.

Scanning Tunneling Microscopy in Madrid, Paul Roman [41-8:446]

A research group at the Institute for Fundamental Physics, Autonomous University of Madrid, makes great strides in both the basic understanding and in unusual applications of scanning tunneling microscopy. current and planned equipment is described, and two research projects with electrochemistry in mind are reviewed as an example.

Gallium Arsenide Research at Stuttgart's Max Planck Institute, Paul Roman [41-8:456]

Pioneering Semiconductor Device Research at Stuttgart University's Physics Department, Paul Roman [41-8:457]

An Exciting Meeting of the Dielectrics Society, Robert W. Vest [41-9:494]

The theme of this year's meeting, held in Cambridge, UK, in April 1987, was dielectric behavior in ordered systems with special reference to ferrolectric and related phenomena. Presentations on relaxor ferroelectrics, other inorganic ferroelectrics, and ferroelectric polymers are reviewed.

Research on Thick-Film Hybrids in Italy (Telettra, Marelli, and the University of Modena), Robert W. Vest [41-9:496]

The research on thick film hybrids at two of Italy's industrial laboratories – Telettra Telecomunicazioni and Mareille Autronica – and the University of Modena is reviewed. Cooperation between the universities, with the fundamental research, and the industrial laboratories, with their applied R&D, has helped Italy to be among the world's leaders in the hybrid industry.

A New Center for Electronics Materials Research in England, Paul Roman [41-9:528]

Research in Superconductivity at Cambridge University, UK, J.F. Blackburn [41-10:551]

The work of Cambridge University's Department of Materials Sciences and Metallurgy is reviewed; in particular, the experiments with sputter-deposited YBaCuO thin films.

Research on Fuel Cells and MOCVD at Imperial College, Robert W. Vest [41-10:553]

Imperial College's work in solid oxide fuel cell research and in metal organic chemical vapor deposition are discussed. The current research activities are in some of the most important areas in electronic ceramics, and, the author believes, should keep Imperial College in the forefront of the technology for the foreseeable future.

Composite Materials Conference in France, Louis Cartz [41-10:555]

Studies presented at this all-French conference on the fiber matrix interface covered the use of acoustic emission, forced vibrations, fragmentation, and microindenting methods. Surface treatments of the fibers were by carbon coatings, nitrogen plasma, and various chemical agents. Presentations were also given on studies of the microstructure surface energies and critical shear stress of the interface.

Fiber-Reinforced Glass Composites at Harwell, Louis Cartz [41-10:590]

High-Density Interconnection Research at the UK's Standard Telecommunications Laboratory, Robert W. Vest [41-10:593]

Some Observations on Hybrid Microelectronics in Yugoslavia, Robert W. Vest [87-01:22]

Visits to the Mihailo Pupin Institute and the Research and Development Institute of Electronska Industrija along with attendance at this year's Yugoslav Conference on Microelectronics form the basis of this profile of the current state of hybrid microelectronics research in Yugoslavia. The author concludes that the quantity of work is quite large in relation to the population while the quality covers the full spectrum.

Engineering Ceramics: A One-Day Meeting in the UK, Louis Cartz [87-01:26]

Presentations at this meeting held in July 1987 concerned the advantages and disadvantages of replacing metal components with ceramic ones. Papers are reviewed under the topics of engineering applications and property requirements, and engineering ceramic properties.

Materials Meeting in London, UK, May 1987, Louis Cartz [87-01:29]

Presentations on the surface treatment and tribology of ceramic materials are discussed – with special reference to plasma-spray coatings and adequate preparation of the substrate. Papers on toughening mechanisms of zirconia-based ceramics, ion implantation, microstructure, and triboloby of ceramic surfaces are also reviewed, and a detailed discussion of WC-Co cemented carbides is given.

Stress Relieving After Welding: Eastern European Approaches, Kenneth D. Challenger [87-01:33]

Presentations given at the annual Assembly for the International Institute of Welding, held in Bulgaria in July 1987, are assessed. Topics under which the papers are discussed are: a new heat source for materials processing, metallurgy of stress relieving, resident stress generation, and mechanical stress relieving.

1st European Workshop on High Tc Superconductors and Potential Applications, Ray Kaplan [87-01:50]

Selected presentations at this workshop, held in Genoa, Italy, in July 1987, are discussed. Topics of this review include ideal structure, structure defects. Tc 92K, theory and conductivity mechanisms, applications, and wires.

Acoustic Levitation of Ceramic Spheres, Louis Cartz [87-01:61]

Containment of Atmospheric Contamination, Louis Cartz [87-01:63]

Sixth European Microelectronics Conference (EMC/87), Robert W. Vest [87-02:17]

The papers presented at this meeting, held in June 1987 at Bournemouth, UK, are briefly summarized under the topics of high-density, interconnection systems, materials in hybrid technology, and surface mount technology.

Creep and Fracture of Engineering Materials and Structures – Third International Conference, John P. Gudas [87-02:19]

Selected presentations given at this conference, held in Swansea, UK, are reviewed. Topics under which the papers are reviewed are: mechanisms of creep and fracture, deformation and fracture of particle-strengthened alloys, creep and fracture of steels, damage accumulation and creep crack growth, and remanent life assessment.

Sialon Ceramics Research at The University of Newcastle-Upon-Tyne, Louis Cartz [87-02:23]

Sialon ceramics are investigated at Newcastle-Upon-Tyne by the group headed by Dr. D.P. Thompson. Nitrogen sialon glasses are shown to be transparent. Methods of overcoming the effects of the glassy grain boundary phase are being investigated.

Materials Research in Göteborg, Sweden, Louis Cartz [87-02:57]

Meeting on Composite Materials in Sweden, March (1988), Louis Cartz [87-02:59]

Mechanical Testing of Engineering Ceramics at High Temperatures, Louis Cartz [87-02:59]

Structural Effects in Amorphous Ferromagnets – An ONRL-Supported Conference Session, Paul Roman [87-02:63]

ESNIB Articles, 1988

The 5th International Conference on High Temperature and Energy Related Materials, Louis Cartz [88-01:38]

This conference was held in May 1987 at Rome, Italy. Selected presentations under the following topics are summarized: levitation by ultrasonic standing waves, lithium ceramics as tritium sources for breeder fusion reactors, the synthesis of TiN by the self-sustaining exothermic reaction of Ti in N_2 gas, and the use of CeS containers for molten metal.

The Bonding of Metals to Ceramics: Studies at Stuttgart, Louis Cartz [88-01:41]

Researchers at the Max Planck Institute in Stuttgart are studying the heterogeneous interface between metal and ceramic by preparing large bi-crystal plates welded under conditions of extreme cleanliness, in ultra-high vacuum, at high temperatures and pressure. Lattice imaging of the interface of Nb/Al_2O_3 shows the atomic planes to be undisturbed, except within 3-4 atomic planes of the interface.

Stainless Steels/87 Highlights Welding of New Duplex Steels, A. John Sedriks [88-02:38]

This report gives a brief overview of the papers presented at the Stainless Steels '87 Conference, which was held in September 1987 at York University, UK. The author states that the most striking aspect was the evidence of the large European R&D effort that has gone into the provision of welding technology for the new duplex stainless steels.

NATO Meeting on Ion Beam Modification of Materials, Louis Cartz [88-02:40]

Selected papers given a this NATO-ASI meeting, held in August 1987 in Viano do Castelo, Portugal, are reviewed. The stated objective of this meeting--materials modification at high fluence – was well covered, and it is on that subject that this report focuses.

Powder Metallurgy Meeting in Switzerland, Louis Cartz [88-02:44]

This meeting, "PM Aerospace Materials 87," was held in November 1987 in Lucerne, Switzerland. The meeting was concerned with the powder metallurgy of the tough, lightweight metal alloys – Ti, Al, Mg, and Li alloys--required by the aerospace industry. Selected presentations under the various relevant topics are summarized.

Fifth European Conference on Internal Friction and Ultrasonic Attenuation in Solids, R.W. Judy [88-03:51]

The six invited lectures given at this conference, held in July 1987 in Antwerp, Belgium are briefly reviewed in this report, along with summarizing comments about the contributed papers in general.

Wear Resistant Materials in France, Louis Cartz [88-03:53]

This meeting, "Surface Treatment of Wear Resistant Materials," was held in November 1987 at St. Etienne, France. Presentations on ion implantation techniques, vapor deposition, and thermal/laser treatment are reviewed.

Engineering Ceramics at the European Research Center at Petten, the Netherlands, Louis Cartz [88-03:57]

This report concerns the high-temperature materials studies, particularly on the stability of materials in severe environments, which are carried out at the European Joint Research Center at Petten. Included are studies of high-temperature corrosion problems, behavior of Si_3N_4 ceramics, corrosion in O, C/O, and S/O atmospheres, and mechanical properties.

Refractories Meeting in Germany, Louis Cartz [88-03:59]

A brief summary of this meeting held in Ocotber 1987 at Aachen, West Germany, is given. Most of the talks were concerned with practical systems.

4th International Conference on Interconnection Technology in Electronics, Robert W. Vest [88-04:17]

Significant new contributions in the areas of material science, design and packaging, and joining technology which were made at this meeting held in February 1988 at Fellbach, West Germany, are discussed.

Materials Science Research Institutes in Madrid, Spain, Louis Cartz [88-04:21]

A brief overview of the work of Spain's Institutes of Materials, Acoustics, and Microelectronics and Microwaves is given. These institutes display a very high level of scientific activity in the best scientific tradition.

Ceramics Research Institute, Madrid, Spain, Louis Cartz [88-04:23]

A variety of this institute's research projects, reviewed in this report, show the quality and range of the work done there. The projects include research in: reaction sintering of zircon-alumina powders, sol-gel processing, electroceramics, copper phosphate glasses, and zirconia, alumina, and mullite ceramics.

Materials Research at EPFL Lausanne, Switzerland, Louis Cartz [88-04:26]

Research at the Ecole Polytechnique Federale de Lausanne (EPFL) in ceramics, metal physics, and polymers is discussed. Of particular interest is the work in superplasticity in ceramics, the Al_2O_3-TiO_2 reaction, the composite formed by AlN-TiO_2 reaction, and the treatment of materials laser.

Chalcogenide Thin Film p-n Devices, Patras, Greece, Louis Cartz [88-04:28]

This is a brief note on preparation of chalcogenide thin film p-n devices by sputtering $Ge_{20}Se_{80}$ onto $Ge_{20}Se_{80}$-2Bi and As_2Te_3 onto $Ge_{20}Se_{70}Bi_{10}$. Sputtering is effective in preparing films of constant composition.

Materials Meeting in Bordeaux: EXPERMAT '87, Louis Cartz [88-05:29]

A very wide-ranging conference on materials was held in France. Hard materials are being sought from compounds having crystal structures similar to EC. Levitation methods of crystal growth are described to provide pure high-temperature materials. Ferroelectric compounds containing bismuth, are being investigated over a wide range of cation substitutions.

Ceramics at EXPERMAT '87, Louis Cartz [88-05:32]

The oxidation of nonoxide ceramics, Si_3N_4, SiC, ZrN, and ZrC has been described, and also the corrosion of Si_3N_4 by SO_2. Precursors of SiC fibers are reviewed. The sol-gel processing of complex silicates and phosphates is discussed. Thin films of Ti-silicide are prepared by a range of methods.

Ion Irradiation Studies at Padua, Italy, Louis Cartz [88-06:22]

Ion irradiation studies are carried out at Padua, Italy, of glasses and ceramics, semiconductor materials, and of metal thin films. The surface compositional changes, and property changes are carefully followed. Surface hardening, antireflection coatings, wave guides, ion beam mixing, and gas incorporation are among the studies in progress.

Summary of the Report on High Temperature Superconductivity Research in Selected Laboratories in West Germany, Donald H. Liebenberg and Alan F. Clark [88-06:29]

Work in superconductivity research at West Germany's University of Giessen, Technical University at Darmstadt, Hoechst AG, Siemens AG, Kernforschungsanlage at Julich, Kernforschungszentrum at Karlsruhe, the Walter Meissner Institute at Garching, and the Max Planck Institute at Stuttgart is briefly noted. The authors give positive marks to West Germany for its well-planned and sustained effort in this area.

ONREUR Reports, 1985

Sixth International Conference on Fracture, Kenneth D. Challenger [C-2-85]

Sixth International Conference on Fracture was held in New Delhi, India, in December 1984. This report discusses work on the mechanisms of fracture, mechanics, fracture of nonmetallic materials, composites, and dynamic fracture. US and UK scientists and engineers are setting the pace for development in the field of fracture, but there are major research programs in Japan, Australia, France, West Germany, India, and China. The use of fracture mechanics for safety analysis and residual life estimation is widespread, but its use in design is still quite limited.

The Damage Tolerance of Carbon Fiber Reinforced Composites – A Workshop Summary, Kenneth D. Challenger [C-15-85]

The workshop in Glasgow, Scotland held on 12 September 1985 included participants from the US, the UK, Australia, and France. This report discusses six critical problem areas associated with damage tolerance of carbon-fiber reinforced composite materials: damage tolerant materials, testing methods, structural life prediction, damage tolerant design concepts, repair methods, and nondestructive testing.

ONREUR Reports, 1986

Welding Research in Scandinavia: An Assessment, Kenneth D. Challenger [R-2-86]

The Scandinavian countries – Denmark, Finland, Norway, and Sweden – are making significant contributions to the science and technology of welding. Specific research topics which should be closely followed by US researchers are hyperbaric welding, CAD/CAM applications to welding, mathematical modeling of the weld process, and hydrogen assisted cracking of steel welds.

ONREUR Reports, 1987

NATO Workshop on the Design, Activation, and Transformation of Organometallics into Common and Exotic Material, Robert W. Vest [7-005-C]

The objective of this workshop was to identify the scope and potential rewards of research efforts in the development of methods of transforming organometallic compounds into useful materials. This report covers the presentations in chemical vapor deposition, sol-gel processing, and preceramic polymers.

The 5th Europhysical Conference on Lattice Defects in Ionic Crystals, Robert W. Vest [7-008-C]

The scientific program of this international conference covered theoretical and experimental studies of defects in metal oxides and halides. This report concentrates on overview presentations of spectroscopy and optical properties; properties related to surface defects deformation and, phase transformations; and various areas of application. It also covers those papers considered important in the sessions on computer modeling and other theoretical approaches and on transport and dielectric properties.

Applied Material Science in Turkey, Louis Cartz [7-013-R]

This report covers visits to several of Turkey's leading technical institutions and provides a survey of some of their facilities and ongoing research in applied material science, primarily with minerals, ceramics, polymers, and elastic constants. The institutes visited included: Middle East Technical University (METU), Ankara; Turkish Scientific and Technical Development Agency (Tübitak), Ankara; Mining Research Institute Ankara (MTA); Tübitak Electronics and Electrical Research Institute, Ankara; Marmara Research Institute, Gebse; and Ankara Nuclear Research and Training Center (ANAEM).

Metal Physics, Université de Poitiers, France, Louis Cartz [7-014-R]

The microstructure of metals is studied by a range of electron optical methods, grazing incidence x-ray diffraction, and conversion electron Mossbauer spectroscopy. The microstructure is related to mechanisms of plastic deformation, defect formation by ion implantation. Dynamic ion beam mixing reactions are being undertaken and studies of surface treatments and modification of surface properties. Superalloys, various alloys involving Cu, Al, Fe, Cr, Ni, Ti are being investigated as well as various precipitates in metals.

Ceramic-Ceramic Composites Meeting in Belgium, Louis Cartz [7-20-R]

The problems of obtaining homogeneous dispersions of multicomponent systems were frequently discussed at this conference. The use of acoustic emission was shown to be a useful NDT analytical tool to detect the presence of microcracks in different places. The composite systems considered at the meeting included: zirconia-toughened aluminum (ZTA), SiC fiber-reinforced pyrex, SiC fiber-reinforced SiO_2 glass matrix, mullite-zirconia-Al_2O_3-SiC, C-fiber-reinforced reaction-bonded SiC, ionic conducting NASICON-glass insulator composites, and AlON-Al_2O_3 composites. The zirconium oxycarbide system, ArO_2-ArCxOy and ZrC-ZrCxOy composites are interesting, novel systems.

Second NATO Workshop on Passive Infrared Optical Materials and Coatings, Robert W. Schwartz [7-031-C]

Discussion of the presentations given at this workshop is organized under the following topics: bulk materials – windows; bulk materials – internal components; bulk materials characterization; hard coatings; antireflection coatings, and characterizations of coatings.

ONREUR Reports, 1988

Nitrogen Ceramics Meeting in France, Louis Cartz [8-004-C]

Presentations given at this meeting – EN17 – held in Rennes, France, in September 1987, are briefly reported. A very wide range of nitrogen ceramics properties was discussed at the meeting, in particular, their chemistry, crystallography, and sintering behavior.

High-Temperature Superconductivity Research in Selected Laboratories in the Federal Republic of Germany, Alan F. Clark [8-011-R]

The superconductivity work at eight West German laboratories is reviewed. The laboratories are (or located at): the University of Giessen; the Technical University at Darmstadt; Hoechst AG; Siemens AG; KFA Julich; KFK, Karlsruhe; the Walter Meissner Institute, Garching; and the Max Planck Institute, Stuttgart.

Sixth International Conference on Composite Materials (ICCM-VI), S.G. Fishman and Y.D. Rajapakse [8-015-C]

Selected papers presented in five of the six sessions held at this meeting in London, UK, are discussed. The areas covered in the sessions these papers were given are: metal matrix composites, ceramic matrix composites, mechanical characterization, impact, and nondestructive testing.

Engineering Materials for Very High Temperatures – An ONRL Workshop, Louis Cartz [8-016-R]

The limitations of present-day materials at very high temperatures are reviewed; silicon nitride based ceramics, silicon carbide, carbon-materials. Near-term and long-term studies are described to improve the performance at temperatures above 1400°C of monolithic ceramics, composites, and ceramic coatings. The full texts of the papers given at the workshop are included.

Appendix B. Materials Science Information from Other Sources

The items of information in this section – mainly abstracts of reports and notes – come from a variety of sources: the European Office of Aerospace Research and Development (EOARD) and the US Army Research Development and Standardization Group (USARDSG) [both housed in the same building with ONREUR], US Embassies in the various countries, the Foreign Broadcast Information Service (FBIS) in both Antwerp and Milan, and others.

The 8th Inter-Naval Corrosion Conference (Abstract of a Trip Report by A.J. Sedriks, the Office of Naval Research)

Dr. Sedriks attended the 8th International Corrosion Conference, which emphasized new technology.

This conference, held every 4 years, enables Navy researchers and engineers from the US, Canada, Australia, New Zealand, and the UK to present, gather, and compare corrosion control information and to identify new Navy-oriented research needs. This year the conference was held on 11-15 April, 1988 at the Royal Naval Engineering College, Plymouth, England, and encompassed new technologies associated with coatings, cathodic protection, copper alloys, stainless steels and nickel alloys, composites, rapidly solidified materials, chlorination, computerized expert systems for coating selection, and ripple-load cracking prediction. Sedriks presented a lecture entitled "New Stainless Steels for the Marine Environment." Other ONR-sponsored work presented comprised ripple-load cracking (NRL), corrosion of composites (DTRC), and the use of computers in corrosion analysis (NUSC).

Composite Material Technology, CADCOMP 88 (Abstract of a Trip Report by J.A. Corrado, David Taylor Research Center)

Dr. Corrado attended the conference, Computer Aided Design in Composite Material Technology, CADCOMP 88, held in April 1988 at Southampton, UK. He says that the conference papers made clear that there is a great deal of development work being pursued in Europe in the area of composite materials and structures. This is especially true, he says, for the universities. The conference was organized into seven sessions:

- Laminated Analysis and Design
- Structural Behavior and Identification
- Thermal Analysis
- Software for Composite Material Technology
- Computer Simulation/Filament Winding/Manufacturing Processes
- Impact and Wave Propagation.

Ceramic and Metal Matrix Composites at Cambridge University, LTC Jim Hansen, EOARD.

At Cambridge University. Dr. Clyne is researching metal matrix composites. Titanium is plasma sprayed onto SiC monofilaments to study interfacial effects. Aluminum reinforced with whiskers and short fibers is extruded in carefully controlled experiments to develop a process minimizing fiber breakage and inhomogeneities.

Ceramic and Metal Matrix Composites at British National Physical Laboratories, LTC Jim Hansen, EOARD.

Dr. McCartney heads current research at the British National Physical Laboratories in modeling and experimentation of both ceramic matrix and metal matrix composites. He has extended the Aveston-Cooper-Kelly model (1971) to cracks of finite width in brittle matrix composites, and he is experimenting with model material systems. Metal matrix composite programs are intended to develop a basic scientific understanding in order to improve material property control.

Changing the Face of Materials: From Coal to Diamond, Dr. W. Simmons, USARDSG.

The common theme of several conferences sponsored by the Army European Research Office (ERO) this summer has been the modification or complete reconstruction of the surfacestructure/properties.

A NATO-Advance Study Institute near Lucca, Italy, 1-9 September 1988, entitled "ION Beam Surface-Modified Ceramics..." dealt with the whole range of ion energies from a few eV to 1 MeV from many ion sources. The depth of modification can be adjusted from few atomic layers to as much as several micrometers. Diamond-like coatings with high hardness, abrasion resistance. and altered electrical and optical properties can be applied on many substrate materials. If thicker coatings are desired simultaneous ion bombardment and vapor deposition is performed to alter atomic structure and density as the material is built up. In this way, graded coatings and interfaces are possible.

The "First International Conference on Surface Plasma Engineering" at Garmisch-Partenkirchen, Germany, 19-23 September 1988, dealt primarily with lower energy ions and atoms hitting the surface. DARPA, which has a significant program interest in this area, supplied funds to the conference through ERO and has other present and pending contracts through our office on surface modification. The fundamental process is generic in nature and applies to the mechanical, electrical, optical, chemical, and magnetic properties of virtually every solid material, be it metal, ceramic, polymer, or composite.

Research on New Materials, Dr. Allen Sessoms, Science Counselor, American Embassy, Paris.

Approximately $667 million in public and private funding is currently spent in France on research on new materials each year. French Research Minister Curien emphasizes that the main problem is not so much to develop new materials in laboratories but rather to encourage technology transfer to industry. In order to mobilize researchers, engineers, and industrialists and, in particular, small to medium-size companies which are not involved enough in these techniques, Curien proposed three types of measures: (1) to further develop research on certain strategic technologies, such as high temperature superconductivity; (2) to improve the circulation of knowledge within the framework of the major technological programs (such as space and nuclear) which contribute to the development of new materials (carbon-carbon or ceramics) or to the modification of existing materials; and (3) to improve coordination within public agencies.

Research into High-Tech Ceramics, Office of Defense Cooperation, American Embassy, the Netherlands.

The Netherlands Energy Research Foundation (ECN) research efforts on ceramics also focuses on potential applications in energy, specifically energy conversion systems. ECN is attempting to develop new ceramic materials leading to new applications in membranes, fuel cells, fiber-reinforced strong ceramics, porous ceramic burner plates and ceramic superconductors. The Dutch National Ceramic Workshop, established at ECN in 1986, concentrates on providing specimens of fine ceramics for research and development at ECN and for Dutch industry.

Gallium Antimonide-Based Devices, Dr. E. Davies, EOARD.

Centre d'Electronique de Montpellier, France, is a CNRS research facility which has a strong semiconductor capability based on the gallium antimonide material system. The Center grows its own GaSb crystals, which are then used as substrates for subsequent epitaxial growth. Devices produced by MOCVD include mid-infrared photodetectors that are compatible with fluoride glass fibers.

Electrostatic coating with synthetic material processes, NTSEU.

The Hafe Manufacturing and Trading Enterprise Company, Budapest, Hungary, has introduced a new electrostatic process. Synthetic particles are charged electrostatically in a high-voltage electric space and subsequently form a deposit on the surface of metal objects. Special treatment of these objects before coating is required; this involves removal of oxides, degreasing, phosphate coating, and drying. Electrostatic synthetic dusting is then carried out with varying materials including epoxy powder, polyester powder, acryl powder, and polyamide powder. These coatings offer varying cost and wear qualities.

Electron Microscopy Studies of Carbon and Ceramics, LTC Jim Hansen, EOARD.

Madame Oberlain at the University of Pau, France, leads a group performing electron microscopy in constituents of composites. Materials studied include carbon fibers, silicon carbide fibers, and graphite. A special technique developed for these studies is dark field imaging in transmission electron microscopy.

Aluminalon, LTC Jim Hansen, EOARD .

Aluminalon, a new ceramic material, has been developed by researchers at Ecole Nationale Superieure des Mines in Saint-Etienne, France. Aluminalon is a dispersion of gamma aluminum oxynitride in an alumina matrix, with no vitreous grain boundary phase. Tribological properties are most notable, especially following oxidation treatment.

Fragmentation and Cracking of Solids, LTC Jim Hansen, EOARD.

Theoretical methods from statistical physics have been applied to cracking and fragmentation of solids. Personnel at SOREQ Nuclear Research Center, Israel, use percolation theory, transport theory, and maximum entropy to model damage in ceramics, metals, and rock.

Ceramics Research at the Technion-Israel Institute of Technology, LTC Jim Hansen, EOARD.

Technion's Professor Brandon is hot pressing ceramic-ceramic composites. He makes laminates of either alumina or cordierite fibers reinforced with Nicolon fibers and uses ceramic whiskers to reinforce alumina. Professor Gal-Or coats and impregnates carbon-carbon composites with thin ceramic coatings (SiC or ZrO_2) using an electrophoretic deposition process. The goal of this research is to produce oxidation-resistant carbon-carbon.

Thermodynamic and Transport Properties in Molten Salts, Sol Gels, and Fluoride Glasses, LTC LaRell Smith, EOARD.

The research group of Professor A.M. Elias at the University of Lisbon is doing excellent research on fundamental transport properties. In addition to recent work on complex formation and its effect on transport properties in chloride molten salts, they have done work on a new method for optical fiber production using sol-gel processing. Hydrolytic polycondensation of tetrametoxy-silane using a low concentration of alpha-picoline, gives SiO_2 gel which was dried at 22°C to a transparent amorphous material. The main advantage of this process is economy, but the research group is also investigating the possibility of producing glasses with new compositions not easily attained by conventional techniques.

Center for Electronic Materials, UMIST, Dr. Eirug Davies, EAORD.

Prominent activities at the UK's University of Manchester Institute of Science and Technology (UMIST) include compound epitaxial growth and an exacting materials characterization program which includes silicon. ZnSe growth on GaAs and Ge is at the forefront of II-VI compound work worldwide. In III-V compounds, material limitations have been identified with trace contamination in the metallo-organic gases used for growth. The difficulty of atmospheric pressure growth on InP is attributed to such contamination and this is now readily circumvented. The Center has also contributed to the evolution of the deep-level transient spectroscopy technique which is used extensively in silicon for evaluation.

Polymer Matrix Composite Research, LTC Jim Hansen, EOARD.

The Dupont Corporation is sponsoring an effort led by Professor Gad Marom of the Hebrew University, Jerusalem, Israel, to determine by modeling how variations of the diazoncyanide interlayer affect composite properties. In another project, fatigue and wear of hybrid composites will be studied in a joint research project between a German and two Israeli universities. Materials to be tested include carbon, aramid, glass and Kevlar fibers, epoxy matrices, and varying-strength interfaces.

International Symposium on Trends and Applications in Thin Films, LTC LaRell Smith, EOARD.

This conference was held in Strasbourg, France, from 17 through 20 March 1987. There were over 300 attendees from Europe, and papers were presented on nearly every aspect of thin films including optics, electronics, magnetics, hard coatings, and analytics. Of particular interest were papers on optical coatings with a very high stability in their optical properties when subjected to temperature and humidity variations (130 to 350°C), thin-film techniques for x-ray mirrors (30-percent reflectivity), new devices using organic semiconducting polymers on semiconducting substrates, thin-film microbatteries, and materials for ohmic contacts on GaAs and CdTe. A brief report on these papers is available along with a full list of papers presented. Copies of any of the papers can be provided and a few copies of the full proceedings will be available.

Deformation and Strain Measurements at Very High Temperature, LTC Jim G.R. Hansen, EOARD.

Electronic speckle pattern interferometry (ESPI) and moire interferometry have been used at the Norwegian Institute of Technology to measure the deformations of white-hot objects. To date, moire measurements of in-plane deformations, that can be used to determine stresses, have been made up to 1300°C. ESPI measurements of out-of-plane deformation have been made beyond 2000°C. Air currents due to the high temperatures were not found to be a considerable problem. To go to higher temperatures with ESPI, a YAG pulsed laser is now being incorporated into the experiments. Cracks in ceramic objects have been measured at room temperature, but will be made at higher temperatures in the future.

Ceramic Components Research in Sweden, LTC Jim G.R. Hansen, EAORD.

The Swedish Institute for Silicate Research (SISR) has been cited by the Swedish National Board for Technical Development as the leader in Swedish R&D in ceramic composites. The modest, 3-man-year effort at SISR is mainly concerned with whisker-reinforced ceramics. Very little work has been done on continuous-fiber-reinforced ceramics. SISR research concentrates on fabrication techniques required by industry. Two patented SISR-developed processes (rate-controlled extraction for injection moulding and nitriding pressureless sintering) developed for monolithic ceramics have been applied to whisker-reinforced ceramics.

Vg Semicon (UK) Oxygen Implanter, Dr. D. Eirug Davies, EAORD.

Dielectrically isolated silicon is required in preference to bulk silicon for radiation hardening. Buried oxide formation through implanting oxygen into silicon is considered one of the more promising approaches for providing the desired material. Several orders of magnitude more ions have to be implanted than is presently done by doping implanters, and Vg Semicon of East Grinstead, UK, is one of the two companies currently developing high-current oxygen machines. The use of an RF ion source, long abandoned in doping implanters, cirucumvents the problem of oxidizing filaments, and the oxygen ions are extracted as seven adjacent beams. Up to 80 percent of the beam is singly ionized oxygen, and to date 55 percent of the extracted beam reaches the silicon target. Sputtering from the nontransmitted beam is significant and requires the use of internal quartz or silicon coating to prevent contamination. The prototype machine is designed as a test vehicle with features beyond the requirements of a commercial system, and the huge 2.5-meter target chamber is yet to be retrofitted with an automated wafer loader. It is currently being operated up to 150 MA with the wafers provided for evaluation as part of the UK Alvey Program.

Five Institutions in Israel interested in Polymers, Dr. Iqbal Ahmad, EAORD.

Dr. Ahmad visited five institutions in Israel for discussions with various Israeli scientists concerning proposals for research and other work they are doing. At the Weizmann Institute, Rehovot, Dr. S. Reich discussed techniques for producing highly conducting metal polymer composites, which can have potential for electromagnetic shielding, and, concerning another study, explained how he is able to precipitate metallic clusters in polymers at predetermined positions – an achievement of potential interest as a basis for write-once, high-density optical information storage. In the same group of researchers, Dr. Jacob Klein is conducting an interesting study on the interaction between mirror surfaces in a polystyrene-cyclopentavine solution; the objective is to measure the forces between thin surfaces. At the Nuclear Research Center (SOREQ), Yvane, Ahmad discussed a research proposal submitted by Dr. Salzmann on the subject of spallation mechanisms of ceramic composites impacted by high energy. At The Hebrew University of Jerusalem he spoke to Professor Henry Selig about his work on the intercalation of graphite fibers, and to Dr. Dan Polotsky about his concept, called NSOM (near-field microscopy. At Technion, Haifa, Dr. Zehave gave Ahmad an overall review of the ongoing work at the institute. At Ben Gurion University, Beer Sheva, Dr. Bernstein discussed his proposal on fundamental studies of conducting polymers, involving a mixed and segregated stack concept.

Material Research at the Fraunhofer Institute, LTC Jim Hansen, EAORD.

West Germany's Fraunhofer Mechanics of Materials Institute has been very active in several areas of materials research. They are currently conducting high-temperature fracture and fatigue tests on ceramics. This work is being conducted in a new division devoted entirely to ceramics. They have also been able to produce some interesting materials using explosive compaction.

Ceramics and Composites in Turbine Engines, LTC Jim Hansen, EOARD.

The DFVLR Institute for Structural Research and Design Development in Stuttgart, West Germany, has developed an impressive ceramics and composites design and testing facility. They have been applying their expertise to the design and testing of turbine engine components made of exotic materials.

Thermal Plasma Research, LTC Jim Hansen, EOARD.

Some of the most advanced research in thermal plasma spraying in Europe is led by Professor Fauchais at the University of Limoges, France. They are world class in experimentation and diagnostics of thermal plasma sprays. Capabilities to measure sprayed particle surface temperature and evaporation in flight are remarkable. Coatings produced from their research include thermal barrier, wear resistant and corrosion resistant coatings of various ceramics. They also study plasma ejected during laser impingement on metals and laser chemical vapor deposition.

Damage Mechanics for High-Temperature Materials at a Leading French University, Jim Hansen, EOARD.

The Laboratory of Mechanics and Technology, at the University of Cachan, specializes in research of damage mechanics for sophisticated aerospace materials. Materials tested include high-temperature metals for turbine disks and carbon-carbon composites. Basic research in damage evolution in these materials is carried out for large aerospace companies, such as SNECMA and Aerospatiale.

Research at the Institute of Metal Forming, Aachen, West Germany, LTC Jim Hansen, EOARD.

Research pertains to forming processes for iron and non-iron metals. Finite element computer models simulate plastic forming processes with global, local, and microscopic analyses. Results of experiments for measuring flow stress and local friction are used to correct models. A computer-driven incremental forging process is being developed, especially for use with aluminum lithium.

Direct Observation of Fracture and the Damage Mechanics of Ceramics, a report under Grant AFCSR-87-0307G by *G. Vekinis, M. Ashby, and P. Ceaumont*, Engineering Department, University of Cambridge.

An experimental study of the R-curve behavior of an Alumina ceramic *in-situ* SEM has yielded detailed information on the extent of the R-curve in this material as well as on the actual physical mechanics responsible for the toughness increase. These have been identified as both ligamentary bridging due to crack bifurcation and bridging by wedged grains between the crack faces which dissipates energy by friction. Simple modeling calculations show that these mechanisms can account for the 75 percent increase in toughness observed using the double torsion technique. Further, the feasibility of Plaster of Paris as a model ceramic material for damage mechanics investigations has been examined, and extensive mechanical property characterization has been carried out. The initiation and final fracture surfaces have been constructed from uniaxial/hydrostatic compression and uniaxial tension, and the results have been compared with new theoretical models for fracture initiation. The failure characteristics have been studied by *in-situ* SEM.

Dispersion Strengthened Aluminum, LTC Him Hansen, EOARD.

Professor Jangg of the Technical University of Vienna, Institute of Chemical Technology, has developed a dispersion-hardened aluminum alloy with Al_4C_3 dispersoids. Produced by reaction milling of aluminum powders with carbon black, a 12-vol-percent carbide alloy has excellent high-temperature properties. A 500°C soak for 100 hours causes essentially no loss in strength, with ultimate tensile strengths of 400 MPa and 180 MPa at room temperature and 500°C, respectively, for laboratory material.

Ultrasonic Fatigue Testing and Powder Processing, LTC Jim Hansen, EOARD.

Two separate research groups at the University of Vienna are applying ultrasonic vibrations to fatigue testing and powder metal and ceramic processing. Fatigue testing is accomplished in a factor of 100 to 1000 reduction in time. Research topics in fatigue include short fatigue crack growth, study of frequency effects, evaluation of Ti and Al-Li alloys, combined load effects and random fatigue loading. Compaction of both ceramic and metallic powders is aided by addition of ultrasonic vibrations.

Physics and Materials Research at the SOREQ Nuclear Research Center, LTC LaRell Smith, EOARD.

A recent visit of SOREQ uncovered several projects of interest to the Air Force. (1) Space Simulation: Dr. Geoffrey Lempert has submitted a major proposal to USAF for the development of a space simulation facility using SOREQ's MIERA facility to reproduce the highly energetic space environment (ions and neutrals). The facility is capable of fluxes of 10^{15} atoms/cc/sec with a possible 100 mA of N^+. (2) Fluoride/Chalcognide Glasses and IR Fibers: the SOREQ group has submitted a preproposal for laser damage measurements in fluoride glasses. In addition they are working on doped glasses for lasing hosts -- particularly as fibers. Finally, Dr. A. Bornstein has developed a method of producing graded index material which could have significant impact on producing lenses. The method involves doping the glasses to produce a specific profile of refractive index. (3) Germanium for IR Applications: SOREQ claims to have the best germanium crystals in the world for IR work. They are producing these commercially through their ISORAD division. They claim that even their largest diameter materials (20-30 cm) are single crystal and they provide an extensive specification set which the materials are guaranteed to meet.

The report provides more detail on the above projects along with specific reprints, extracts, and the preproposals.

Thermal Barrier and Other Plasma Sprayed Ceramic Coatings, LTC Jim Hansen, EOARD.

Dr. I. Kvernes directs several Norwegian industrial efforts in plasma spraying ceramic coatings that act as thermal, corrosion, and wear-resistant coatings. A unique technique allows coatings to be plasma sprayed underwater, with considerable economic and technological benefit, e.g., low-oxide bond coats. Zirconia coatings are produced silica free, to increase fracture toughness, and with silicon carbide whiskers. Aluminum and magnesium are coated using patented bond coats of rapidly solidified powder to pass stringent thermal fatigue requirements.

French Ceramic-Ceramic Composite Technology Applied to HERMES, the European Space Shuttle, LTC Jim Hansen, EOARD.

Information on the structural and thermal protection systems for HERMES was exhibited at the Paris Air Show. SEP and Aerospatiale are competing for the hot-structures contract. The SEP design features silicon carbide or carbon fibers in a silicon carbide matrix, while Aerospatiale emphasizes protected carbon-carbon. A SEP silicon carbide-silicon carbide composite segment of the wing leading edge has already been successfully tested. Dassault Bréguet will test the structures in a new thermal test facility with plasma jet heating.

Thermal Diffusivity in Composites, LTC Jim Hansen, EOARD

Dr. Roy Taylor of the University of Manchester Institute of Technology is an internationally acclaimed expert on thermal diffusivity. He uses a laser flash system for diffusivity in composites. He has done extensive work with carbon-carbon and is now modeling the SEP silicon carbide composites.

Silicon on Insulator Workshop, Dr. Eirug Davies, EOARD.

A recent Silicon on Insulator Workshop shows that competitive European efforts exist for producing IC-compatible, isolated films of silicon. The innovation of higher furnace annealing with oxygen-implanted "Simox" material originated in France's Grenoble area laboratories. Probably the most advanced work on porous silicon currently pursued is in the UK and France. Island dimensions vary with circuit layout to provide sidewall isolation. For zone melt recrystallization, the tendency is to configure three-dimensional structures around seed openings and defect regions within the recrystallized material. This is in common with the Japanese approach, and the work has not produce subgrain-free material for single layer use, as is currently becoming available in the US.

Advanced Composites and Information Technology at Devtech, LTC Jim Hansen, EOARD.

The Devtech company in Heerlen, Netherlands, uses a strong mathematical basis founded in topology to solve, with the aid of artificial intelligence, complex materials, engineering, and information technology problems. Materials developed include *in situ* ceramic-ceramic composites, claimed cheaper to produce than cast iron. Intelligent manufacturing of thermoplastic composites is being scaled to large size. In the information technology area, data compression of 10,000:1 has been demonstrated.

Gallium Arsenide and Related Compounds 1987, A. Christou and H.S. Rupprecht, USARDSG.

The Fourteenth International Symposium on Gallium Arsenide and Related Compounds was held in Heraklion, Crete (Greece) from 28 September to 1 October 1987. Two hundred research papers were presented at the symposium in three plenary sessions, the regular sessions, and poster sessions. The symposium papers were selected from over 275 abstracts submitted to the Technical Program Committee for evaluation. The symposium was highlighted by 11 invited speakers in the areas of: DX centers, advanced MOCVD optoelectronic devices, electronic states in superlattices, polar-nonpolar epitaxy, delta doping, integrated guided waves optics on III-V semiconductors, wave function engineering, rare earth injection lasers, below bandgap photoresponse of undoped GaAs, Raman scattering of superlattices, and stable ohmic contacts.

Shock Waves in Laser Pulsed 2-D Carbon-Carbon Composites, Dr. W. Simmons, USARDSG.

I. Gilath and S. Eliezer describe in their Third Progress Report "Damage in 2-D Carbon-Carbon Composites by Short Pulsed Laser Induced Shock Waves" ongoing research at SOREQ Nuclear Research Center, Israel. A high-irradiance single-beam short-pulsed Nd:glass laser was used to generate shock waves in 2-D carbon-carbon composites. Dynamic brittle fracture at ultrahigh strain rate was observed as a result of reflected shock waves as tensile waves from the back surface of samples. Successive stages of damage from incipient spallation to complete sample perforation were obtained by increasing gradually the laser energy. The thermomechanical damage on the front surface as a result of laser interaction with the target material, and the mechanical damage at the back surface as a result of shock wave reflection were characterized by optical and scanning electron microscopy. The failure properties of the composites were related to the processing of densification and graphitization mode.

Oxynitride Glasses and Glass Ceramics, Dr. Simmons, USARDSG).

Dr. Stuart Hampshire, Limerick, Ireland, reported in his Fifth Periodic Report, the glass transition temperature, the crystallization temperature and devitrification characteristics at various temperatures for various glass compositions in the general scheme MA-Si-MB-O-N at a standard cation composition equivalence. Large baties of glasses (80-100 g) were successfully prepared in a imber of systems by melting compositions at 1700°C for hour in nitrogen. The glass is cast into heated graphite olds at 900°C, annealed at that temperature for 1 hour, ien slow furnace cooled. Differential Thermal Analysis)TA) is used to determine the glass transition temperaire (Tg) and the crystallization temperature (Tc). From iese results, suitable heat treatment programs can be esiblished for the production of glass-ceramics. The glass-:ramics process normally consists of a two-stage heat eatment during which nucleation of crystals and crystal rowth occurs. The first stage is usually carried out at aproximately 50°C above Tg and the second stage at the o-called crystallization temperature (Tc).

Polymeric Composite Materials, Dr. W. C. Simions, USARDSG.

In situ microstrain testing of individual fibers in a omposite structure was the topic of a 25 February 1988 ite visit to Professor Young, University of Manchester nstitute of Science and Technology. Professor Young's ;roup has been investigating polydiacetylene single-crysal fibers in epoxy and thermoplastic matrix composites. They have developed an optical Raman back-scattering echnique to determine the distribution of strain along the urface of the fiber in regions of 25-μm diameter. Strain ibsolute accuracy is claimed to be measured by +0.1 per-:ent.

Control of Dislocation Impurity Atmospheres, I.E. Bondarenko, Ye. B. Yakimov (from FBIS Weekly Summary).

I.E. Bondarenko, Ye. B. Yakimov, et al., affiliated with the Institute of Problems of Microelectronic Technologies and Superpure Materials attached to the USSR Academy of Sciences, presented a paper on the effect of dislocation impurity atmospheres on the properties of semiconductors. The data presented show that the properties of local regions adjacent to dislocations are mainly determined by impurity atmospheres. In some cases, impurity atoms interact with dislocation centers, changing their electrical activity. The dependence of the properties of the regions around dislocations on thermal treatment conditions as well as on impurity content opens up possibilities for controlling these properties.

Elimination of Unwanted Effects of Inactive Impurities, V.V. Yemtsev (from FBIS Weekly Summary)

V.V. Yemtsev of the A.F. Ioffe Physical Technical Institute, attached to the USSR Academy of Sciences, presented a topical literature survey on the interactions of intrinsic point defects with electrically inactive impurities in silicon. From his sources he found that electrically inactive impurities in silicon technology can produce unwanted effects upon properties of materials being subjected to heating, quenching, and irradiation. Such impurities can most often be electrically activated due to interactions with intrinsic point defects. The paper outlines the main results collected in the literature by many investigators.

Point-Defect-Related Dopant Diffusion, H.B. Erzgraber, H.J. Erzgraber (from FBIS Weekly Summary).

Erzgraber, et al., affiliated with the Institute of the Physics of Semiconductors attached to the GDR Academy of Sciences, explained some aspects at modeling of point-defect-related dopant diffusion. It was discussed that point defects play a key role in impurity diffusion at high temperatures and under oxidizing conditions, but up to now correct modeling of the point-defect-dependent dopant diffusion has been problematical. One of the reasons is a large scattering of the parameters that determine the point defect -- and therefore the dopant -- behavior. Another reason is the very complexity of the material-dependent influences on the generation-recombination processes of point defects at the surface and the bulk regions. The authors conclude that for comparing experiments with numerical simulation results, it is necessary to start with silicon material that is exactly described with regard to oxygen, carbon, and nitrogen contents, as well as thermal history.

France's Aerospatiale Improving Resin Processing Techniques, J.M. Soret and A.A. Piroux (from FBIS Weekly Summary).

In "Composite Materials Processing," J.M. Soret and A.A. Piroux discuss resin reticulation processes noting that a thermomechanical analysis which provides accurate measurement data is needed to fully control composite processing. To this end, Aerospatiale has developed a "vanhograph" to determine the conditions under which resins reach maximum fluidity and optimal hardening. The device consists of two horizontal grips which hold a plane piece in a chamber with programmable temperatures (-70 to 250°C). The grip moves in sinusoidal motion, while the shear transmitted by the test piece indicates the prepreg's relative rigidness and level of polymerization.

Advanced Materials Research at Harwell Laboratory, (from FBIS Weekly Summary [from a report published in *London Metals and Materials*, No. 4, March 1988]).

The article describes a few areas of the extensive R&D program at Harwell Laboratory. Details of work on materials development and characterization are given. This includes studies of the development and characterization of nuclear fuels and cladding material, structural integrity of materials, manufacturing routes and applications for engineering ceramics, and the sol-gel processes for the production of inorganic oxide powders. Work on high-performance composites is also described, including filament winding and properties of resins.

High-Performance Refractory Linings, D.A. Bell and F.T. Palin (from FBIS Weekly Summary [from a report published in *Reigate (UK) Materials & Design*, No. 9, Jan-Feb 1988]).

D.A. Bell and F.T. Palin of the British Ceramic Research Association describes research into the design of refractory linings using computer-based thermochemical analysis. They report that optimum performance of refractory linings was achieved through improved design based on computer analysis of thermochemical data, e.g., thermal conductivity, diffusivity, expansion, and stress-strain behavior in flexure and compression. Experimental time-temperature results were obtained from thermocouples attached to a steel shell lined with refractory materials (mullite brick, silicon carbide, or silica mortar). Following a complex heating schedule, the measured values were within 10 K of the predicted temperatures. Based on stiffness values from the computer, an estimated stress field in cylindrical linings compares favorably with stress lines measured with strain gauges welded onto the shell at several points. The importance of critical balance between cost and degree of insulation for thermal design is highlighted along with the necessary considerations for expansion allowance required for satisfactory mechanical design.

Microstructure Properties of YAG Ceramics, from FBIS Milan Weekly Summary [from Philips Journal of Research]).

Researchers at Philips Research Laboratories in Eindhoven, the Netherlands, have reviewed the powder preparation of $Y_3Al_5O_{12}$ (YAG) and the sintering of YAG powder compacts to translucency. The influence of processing parameters on the resulting microstructure and mechanical properties is discussed, and some new results on the optical properties and resistance to sodium corrosion are included. The results obtained for YAG are compared with the data for alumina.

Research on Metalorganic Vapor Phase Epitaxy, P. M. Furjlink (from FBIS, Milan, Weekly Summary from *Philips Technical Review* 43]).

Researchers at the Laboratoire d'Electronique in Limeil-Brevannes, France, have reported on research on metalorganic vapor phase epitaxy of multilayer structures with III-V semiconductors. In an article in the Dutch publication, *Philips Technical Review*, they present the results of research using heterostructures with modulation facilities. Vapor phase epitaxy with metalorganic reactants is a good process for cultivating multilayer structures with semiconductor materials such as GaAs and Al(ind x)Ga(ind 1-x) As. Precise regulation of the growth parameters results in surface layers in the monomolecular field. The quality of the surface layers and depth profiles can be judged using spectroscopic ellipsometry.

Progress in Ceramics Research, Dr. Gerald Whitman, Science Counselor, American Embassy, Rome.

The director of CNR's Institute for Electronic Theory and Structures noted the growing capabilities of Italian industry to produce technologically advanced ceramic material. Industries such as SAMIM and Enricerche of the ENI Group, CSM (Centro Ricerche Materiali) of Ansaldo, and Montedison are initiating significant research in ceramic materials. Moreover, one of the four subprojects of the new CNR-finalized project on "special materials for advanced technologies" is dedicated to neoceramic materials. The project covers process technologies, structural ceramics, electroceramics, and glasses; the estimated cost for 5 years is 28 billion lire (about $21 million). It will involve 50 research groups with industry participation at about 40 percent.

National Center for Materials Research and Development Being Developed, Dr. Gerald Whitman, Science Counselor, American Embassy, Rome.

The Puglia region, the Italian National Research Council (CNR), the Italian National Agency for Nuclear and Renewable Energies (ENEA), the Second University of Rome, the University of Lecce, and the financing society Finpuglia formed a consortium to establish a National Center for Materials Research and Development in Brindisi. the center will start operating in the fall under the direction of Professor Paolo Cavallieri, vice president of the CNR national committee for physics. It will focus on the development and the identification of new areas for the applications of metallic materials, semiconductors, and ceramic materials.

Focus on Advanced Ceramic and Neoceramic Materials, Dr. Gerald Whitman, Science Counselor, American Embassy, Rome.

The Director of the Italian National Research Council's (CNR's) Institute for Electronic Theory and Structures noted the growing capabilities of Italian industry to produce technologically advanced ceramic material. Industries such as SAMIM and Enricerche of the ENI Group, Centro Richerche Materiali (CSM) of Ansaldo, and Montedison are initiating significant research in ceramic materials. Moreover, one of the four subprojects of the new CNR-finalized project on "Special Materials for Advanced Technologies" is dedicated to neoceramic materials. The project covers process technologies, structural ceramics, electroceramics, and glasses; the estimated cost for 5 years is 28 billion lire (about $21 million). It will involve 50 research groups, with industry participation at about 40 percent.

Minister of Research Creates Committee for Advanced Materials, Dr. Gerald Whitman, Science Counselor, American Embassy, Rome.

The minister of scientific research has created a committee of experts to manage research in advanced materials. The committee has the task of developing an advanced materials research program and of coordinating existing programs. Present efforts include the finalized projects of the national research council some projects carried out by the National Agency for Nuclear and Renewable Energies (ENEA) and the "Material Physics Projects" of the Interuniversity Consortium for the physics of matter. The committee will also pursue initiative to develop professional training among young scientists and experts.

Conference on the Technology of Amorphous Silicon Dioxide, (Abstract of a Trip Report by Dr. Richard F. Haglund, Jr., Vanderbilt University).

Dr. Haglund attended the Conference on the Physics and Technology of Amorphous Silicon Dioxide, held in July 1987 in Les Arcs, France, where he presented the results of ONR-sponsored research in this area of study. This conference was one in a continuing series of workshops highlighting applications of amorphous silicon dioxide in fields ranging from microelectronics to genetics for fusion lasers. Haglund states that some participants seemed to feel that little progress had been made in the fundamental scientific understanding of amorphous silicon dioxide, particularly the dynamical aspects of defect formation and their role in material damage. This was sharply contrasted, he says, with remarks about the state of amorphous silicon dioxide technology, which seems to be progressing at a very rapid pace. From a series of conversations with Professor Noriyaki Itoh (University of Nagoya, Japan) Haglund reports that Itoh's laboratory has recently received a large infusion of funding for study of the short-time-scale dynamics of exciton formation and deformation in insulators.

Another note of interest resulted from a visit with Professor H. Huber (Wilhelm-Pick-Universität, Rostock, East Germany): Rostok and others at the university have been able to pull together a large consortium of industrial and university collaborators to work in areas as diverse as ion-, electron- and synchrotron radiation-induced damage and processing in fused silica and related electronic materials. Concerning the conference as a whole, Haglund says that most of the applications discussed revolved around microelectronics. Dr. Haglund also attended the Fourth International Workshop in Radiation Effects in Insulators, which was held in Lyons, France, also in July. This conference was concerned with following the classic trends in the fields of sputtering, radiation-induced defect formation in bulk materials, and the effects of radiation on material structure. Haglund points out, however, that the conference program (attached to his report) indicates increased interest in radiation damage in polymers, more interest in electronic mechanisms of radiation damage, and an increased interest in surface damage and desorption. There were several papers dealing with the subject of radiation damage mechanisms due to dense electronic excitation, both in crystals and in glasses.

Gallium Arsenide and Related Compounds 1987, A. Christou and H.S. Rupprecht, USARDSG.

The Fourteenth International Symposium on Gallium Arsenide and Related Compounds was held in Heraklion, Crete (Greece) from 28 September to 1 October 1987. Two hundred research papers were presented at the Symposium in three plenary sessions, the regular sessions, and poster sessions. The symposium papers were selected from over 275 abstracts submitted to the Technical Program Committee for evaluation. The symposium was highlighted by 11 invited speakers in the areas of: DX centers, advanced MOCVD optoelectronic devices, electronic states in superlattices, polar-nonpolar epitaxy, delta doping, integrated guided waves optics on III-V semiconductors, wave function engineering, rare earth injection lasers, below bandgap photoresponse of undoped GaAs, Raman scattering of superlattices, and stable ohmic contacts.

Ceramics Research in West Germany The US Embassy Perspective

This two-part overview of ceramics research in the Federal Republic of Germany (West Germany) was originated by the Office of the Science Counselor at the US Embassy in Bonn. Inquiries should be directed to the Science Counselor, Edward M. Malloy, American Embassy, APO New York 09080.

1. The West German Government-Industry Program in Advanced Ceramics Research

The BMFT's Research Support Program

As part of the 10-year (1985-1994) plan for supporting materials research, the Federal Ministry of Research and Technology (BMFT) committed itself though 1986 to fund over half the cost of 53 research projects in advanced ceramics. Carrying out the research projects and accounting for up to half their costs are some of Germany's leading firms and institutes. Daimler-Benz is developing and testing the use of advanced ceramics for building automotive parts. Hoechst and Hutschenreuther are working on parts for gas turbines. Feldmühle is studying the use of ceramics in gaskets and bone implants. The Max-Planck-Institute for Metal Research in Stuttgart is developing ceramic materials able to withstand high temperatures and stresses. The Fraunhofer Institutes of Non-Destructive Material Testing, Production Technology, and Material Mechanics work on quality assurance of ceramic components in mass production.

Ceramics is only one of the five priority areas in the BMFT's materials research program. The other four are powder metallurgy, metallic high-temperature materials, compound materials, and polymers. Through 1986, the BMFT has agreed to fund 384 projects valued at \$500 to 600 million. Coordinating this program for the BMFT is the Materials Research Group in the Nuclear Research Center in Jülich. In addition to advancing materials research, the program aims at promoting research cooperation between industry and research institutes. For example, Hoechst Ceramtech is developing ceramic construction elements of a gas turbine in cooperation with the subcontractors Daimler-Benz, the technical universities in Karlsruhe and Berlin, and the German Aerospace Research Establishment (DLR [formerly DFVLR - see page 73]). Hutschenreuther, as main contractor, and the Fraunhofer Institute of Non-Destructive Material Testing, as subcontractor, are jointly developing manufacturing processes and technologies for ceramic components.

From 1985 to 1994, BMFT is devoting DM1.1 billion (\$650 million) to materials research in five priority areas:

- High-performance ceramics
- Powder metallurgy
- Metallic high-temperature materials
- Compound materials
- New polymers (engineering plastics).

The material research program is rounded by a sixth research subject, the investigation of friction in mechanical processes and its influence on wear-and-tear processes.

The program provides funding measures covering the spectrum of research activities from applications-oriented research to precommercial technical development. The main objective of the program is the mobilization of scientific and technological manpower in universities, research centers, and industry and the concentration of research activities to strengthen the competiveness of the German industry in the world market. To foster efficient cooperation between industry and research institutes, the government has developed a funding scheme that focuses on joint institutional and industrial research activities. West Germany still holds a strong position in traditional areas of materials research because of its high-quality evolutionary research and development but not in more innovative material developments. Both, the federal government and industry associations emphasize that despite certain weak points in materials research, German trade in high-quality goods will not be jeopardized.

Among the traditional areas of materials research in which West Germany excels is conventional structural materials, including metallic and nonmetallic materials, ceramics, and glass materials. It is especially strong in the fields of iron and aluminum, which have elementary importance for the construction of industrial facilities, machines, and apparatus as well as for the automobile construction. However, the research and development capacities of companies of this production area have to be evaluated in quite different ways. While small and medium-size enterprises normally only concentrate on quality assurance and improvement, few means are available for risky, expensive, and long-term research activities. These activities are left for the scientific institutes and large companies with their own research laboratories, which are mostly well equipped with respect to scientific staff and research devices.

Quite different is the situation in the field of innovative high-performance materials, such as ceramics, compound materials, titanium, and superalloys. In these fields, West Germany occupies a weaker position than the US and Japan. To bridge this gap, the federal government initiated the 10-year materials research program. After a 2-year running phase, BMFT has now provided a first evaluation. Results of the program's effectiveness are promising. Through 1986, 284 projects had been initiated and funded by the BMFT with an average funding rate of 50 to 60 percent of the project costs. According to the Ministry, some promising results have already been achieved with materials in the avionics area, jet propulsion technology, electronics, machine tool manufacturing, and process engineering.

The BMFT Materials Research Program

The governmental materials research program focuses on technically and commercially risky projects. After a 3-year period, BMFT has now published an intermediate state-of-the-art report to reevaluate the goals, priorities, and required financial means which may also lead to a modification of the program. Coordination of the projects is conducted by the nuclear research facility Kernforschungsanlage (KFA) at Jülich with its project leading group on material research (Projektleitung material-und Rohstofforschung [PLR]) acting on behalf of the BMFT. PLR is divided into three sections, the first covering research on ceramics, powder metallurgy, steel research, and coordination of EC projects carried out in the framework of the Cooperation on Scientific and Technological Research (COST) joint EC research program. The second section covers high-temperature metals as well as other specific materials, tribology, material separation (metallurgy and metal processing), and marine (seabed-exploited) materials. The third section deals with new polymers, compound materials, and membrane and catalytic technology.

The PLR is headed by Dr. Neumann and its two ceramics sections by Drs. Jeltsch and Kollenberg. Through 1986, the PLR had supported 384 projects within the scope of the materials research program and the research area of tribology. Table 1 provides a survey about the total estimated costs, the funding volume (through the BMFT), and the average BMFT funding percentage of all projects funded to date in the scope of the federal material research program.

Table 1. Financial volume of material research projects, filed with the BMFT through 1986. ($1.00 = DM 1.75).

Research Subjects	Total Funding Commitments Million DM ($ Million)	BMFT Share in Funding Million DM ($ Million)	BMFT Share in Funding (Percent)
Ceramics	148 (85)	74 (42)	50
Powder Metallurgy	98 (56)	58 (33)	59
Metallic High-Temperature Materials	84 (48)	57 (33)	68
Compound Materials	134 (77)	72 (41)	54
New Polymers	149 (85)	80 (46)	54
Tribology	28 (16)	21 (12)	75
Total	641 (367)	362 (207)	57

Advanced Ceramics. Within the broad field of application of ceramics, the interest in these materials has shifted from household, construction, sanitary, and fire-resistant ceramics towards the advanced ceramics including metal-oxides, nitrides, carbides, and borides or the combination of these compositions as well as glass ceramics and some specific sorts of glass.

In the framework of the BMFT's materials research program, research activities in the field of advanced ceramics focus on four essential subjects:

- Basic developments of ceramic components and production processes, including quality control
- Development of new production processes of ceramic powders
- Development of new production processes of ceramic prototype construction elements
- Development of joining processes and techniques of ceramics in combination with other materials.

Table 2 provides data on the funding of these subjects.

Table 2. Projected financial commitment for research on advanced ceramics, filed with the BMFT through 1986.

Research Subjects	Total Funding Commitments Million DM ($ Million)	BMFT Share in Funding Million DM ($ Million)	BMFT Share in Funding (Percent)
Ceramic Components	36.4 (20.8)	19.6 (11.2)	53.8
Ceramic Powders	11.8 (6.7)	6.7 (3.8)	57.0
Ceramic Construction Elements	94.8 (54.2)	44.6 (25.5)	47.1
Joining Processes and Techniques	5.2 (3.0)	2.6 (1.5)	50.0
Total	148.2 (84.7)	73.5 (42.0)	49.6

Basic Development of Ceramic Components. In the field of development of new ceramic components and production processes, including quality control, research activities concentrate on a systematic investigation of ceramic components to improve the understanding of their material structure. These investigations include:

- Computer-aided research in the analysis of ceramic structures
- Basic research work in ceramic powder synthesis, casting and precision processing, high-purity processing technology, improvement of material strength through development of new crystallization processes, and analysis of material failure
- Research on the correlation between microscopic and macroscopic material characteristics
- The development of nondestructive test procedures for quality control.

The BMFT has therefore agreed to provide DM19.6 million ($11.2 million), corresponding to an average funding rate of 53.8 percent of a total of DM36.4 million ($20.8 million) in research projects on ceramic components. Through 1986, fundings amounted to DM3.5 million ($2.0 million).

Ceramic Powders. In the area of development of new production processes of ceramic powders, priority research projects focus on:

- Production of powders of a dense packing of the powder particles below a critical grain or particle size
- Production of powders of a defined composition and extreme purity
- Production of finest crystalline and amorphous powders
- Improvement of sintering capabilities via additives, such as Y_2O_3, strontium oxides (SRO), and Al_2O_3
- Development of alternative production processes of ceramic powders by means of laser technology and reaction spraying
- Systematic screening and development of ceramic materials with increased mechanical and thermal cyclic loadings, such as Al_2O_3 and Cr_2O_3 oxides with zirconium oxide (ZrO_2) additives, zirconium oxide modifications, high-temperature silicon nitride alloys such as silicon-aluminum-oxygen-neon or silicon-nitrogen-yttrium-oxygen compositions, or non-oxide ceramics, such as silicon carbide, boron nitride, or boron carbide.

In the scope of the development of new processes of power production, emphasis is also laid on the hydrothermal synthesis of oxygenous ceramic powders with respect to their agglomeration characteristics, flame hydrolysis, and flame ammonolysis (chemical reaction in which one or more atoms of hydrogen in the ammonia are replaced by other atoms or radicals) for the production of oxides and silicon nitrate (Si_2N_4) powders, plasma synthesis of Si_3N_4 powders, as well as the characterization of ceramic sintering powders and their classification for various production processes. This part of the ceramics research program is budgeted, therefore, with a total of DM11.8 million ($6.7 million) with a public funding volume of DM6.7 million ($3.8 million), which corresponds to an average public funding ratio of 57 percent. Funding through 1986 amounted at DM1.5 million ($0.85 million).

Development of Ceramic Construction Elements. The majority of projects which have been started or carried out in the scope of the ceramics research subprogram concentrate on the development of production processes of ceramic prototype construction elements. With this objective, it continues the BMFT research project entitled "Ceramic Construction Elements of a Gas Turbine for Motor Vehicles," which was launched in 1974 and which focused on the development of ceramic materials for motor vehicle gas turbines, ceramic construction elements for Otto and diesel piston engines, and catalyst ceramics. Within the framework of this project, the BMFT funded the development of materials for gas turbines (as shown in Table 3) from 1974 through 1983, with DM53.1 million ($30.35 million) and from 1980 through 1986, the development of construction elements for piston engines and catalyst ceramics with DM12.2 million ($7.0 million).

Table 3. Public funding of research on ceramic construction elements.

Priority Projects	Period of Funding	Public Funding Million DM ($ million)
Ceramics for motor vehicle gas turbines	1974-1983	53.1 (30.35)
Ceramic construction elements	1980-1986	8.3 (4.75)
Catalyst ceramics	1984-1986	3.9 (2.23)

Research objectives of the new subprogram focus on:

- The extension of a variety of ceramic materials applicable on construction parts

- Development of adequate production processes, such as nearly isostatic compression, injection molding, and sintering by compression followed by secondary compression based on the ceramic powder-specific synthesis and process requirements
- Development of selected construction units of increasing complexity in shape and application profiles with respect to a future large-scale production
- Improvement of nondestructive test procedures
- Extension of experience in constructing with ceramic materials.

Projected total funding commitments amount to DM94.8 million ($54.2 million) with a BMFT contribution of DM44.6 million ($25.5 million), corresponding to a 47.1 percent funding ratio. Through 1986, the BMFT spent DM8.6 million ($4.9 million) for prototype ceramic construction elements.

Joining Processes and Techniques of Ceramics. In its research goals, this subprogram points to an improvement of joining processes of ceramics with ceramics and ceramics with metal alloys. For application of ceramics at temperatures below 80°C specific soldering methods are investigated by using ZrO_2, Al_2O_3, Si_3N_4, and SiC together with steel, cast iron, and nickel alloys. The soldering methods are tested and analyzed at prototype construction units with respect to their application limits and especially to the life endurance of such joinings. For projects, filed with the BMFT through 1986, total funding commitments from government and industry were budgeted with DM5.2 million ($3.0 million), of which the BMFT contributed DM2.6 million ($1.5 million).

2. Industrial and Institutional Research Activities

The German Ceramic Industry, including all branches such as household and sanitary ceramics and ceramic tiles manufacturing as well as technical ceramics, has reached in 1987 a total turnover of DM7.0 billion ($4.0 billion) with an employee total of approximately 80,000. To this total turnover, advanced ceramics contributed with approximately DM0.5 billion ($0.3 billion) corresponding to 7.0 percent of the total turnover, which reflects the still minor economic role of this branch. This is considered as a completely unsatisfactory result, because technical ceramics, including also conventional technical ceramics besides the advanced ceramics, had already reached a world market volume of DM13 billion ($7.4 billion) in 1985 with a continuously growing tendency. With respect to the large market potential of advanced ceramics, German research efforts have specifically concentrated on the development of ceramics for gas turbines and the hot parts of automobile engines. As a result of these research activities, a ceramic gas turbine prototype is running in a Mercedes-Benz car. According to a survey of the Bayer AG, single parts such as ceramic exhaust portliners made of Al_2TiO_5, are already used commercially, while a variety of other ceramic engine components such as:

- Glow plugs of Si_2N_4
- Valves and valve seats of Si_3N_4 and ZrO_2
- Turbocharger rotors of Si_3N_4 or SiC
- Precombustion chambers of Si_3N_4
- Swirl chambers of Si_3N_4
- Piston crowns of Al_2TiO_5 or ZRO_2

are still in the development or test running phase. Despite great research efforts, a remarkable breakthrough in wide commercial application of ceramic engine components has not yet taken place. Scientists admit that scientific and technical problems were underestimated and that a lot of those problems have still to be solved in close cooperation with industry, large-scale research facilities, and universities.

Industrial Research Activities

Numerous industrial companies, research laboratories, and university institutes are involved in research projects funded through the Materials Research Program. (See Table 4.) However, even a locally based trend in bringing together companies, research facilities, and university institutes for establishing so-called research centers as they are successfully operated in the field of other high-technology areas, such as biotechnology, cannot be detected, so far. On the other hand, recent acquisition activities of large chemical companies, such as Bayer and Hoechst, or their commitment to small ceramics manufacturing companies indicate that the German industry has accepted the technological challenge with respect to the large innovative potential and profits expected.

Besides the large chemical companies – Bayer, Hoechst, and BASF, as well as the large automobile manufacturers Daimler-Benz and Volkswagen – some smaller companies have developed noticeable activities in the field of technical and especially advanced ceramics research and manufacturing.

Table 4: European companies involved in advanced ceramics. (Source: Bayer AG)

German Companies	Other European Companies
Audi (Automobiles)	
AEG-KANIS	
BASF	ICI
Bayer/PK	Cookson
Bayer/CFL Roedenthal	Rolls-Royce
Bayer/H.C. Stark, Berlin	
BMW	
Bosch	
Brown, Boveri & CIE	Baikowski
Daimler-Benz	Desmarques
Degussa	Ceraver
Didier	Pechiney
Dynamit-Nobel	Renault
Feldmühle (Paper Mills)	Rhone-Poulenc
Friedrichsfeld	SEP
Hoechst-Ceramtec	
Hoechst/ESK	
Hoechst/SIGRI	
Heraeus	Asea
Hutschenreuther	Alkem
Kraftwerk Union	Kema Nord
Krupp Widia	Sandvik
MTU	United Turbine
Porsche	Volvo
Volkswagon	
	Fiat
	Montedison
	Lonza

Hutschenreuther, a traditional ceramics manufacturer, for example, is going to acquire various small, profitable ceramics companies. After the acquisition of two small companies for electric and electronic ceramics and after a cooperative commitment with the Degussa company in the field of ceramic catalysts production, Hutschenreuther has now started the operation of a production site for advanced ceramics established with a financial commitment of DM6.0 million ($3.4 million). Production at the new manufacturing site focuses on slide rings of SiC for pumping systems with strong wear-and-tear problems. To date, Hutschenreuther has invested approximately DM15 to 20 million ($8.6 to 11.4 million) for advanced ceramics. According to its own statements, Hutschenreuther makes an annual average turnover in technical ceramics of DM30 million ($17.1 million).

In the framework of the BMFT's Materials Research Program, Hutschenreuther conducts research on three projects: the first project covers the development of a high-compression die casting process for manufacturing nonsymmetric complicated components of Al_2TiO_5 and SiC for piston engines and gas turbines. The project is carried out in cooperation with Daimler-Benz, Degussa, and Lonza. The second one deals with the development of a production process for ceramic rotors of a pressure wave charger based on sintered Si_3N_4 and SiC performed in cooperation with Degussa, Brown, Boveri, and CIE. The third project focuses on an improvement of production processes for sintered SiC. Financial volume of the three projects amounts to DM9.1 million ($5.2 million).

Feldmühle company, Germany's largest paper manufacturer is another example of German industry's commitment to ceramics research. Feldmühle had already started its activities in the international ceramics business in the early 1950's, concentrating on advanced ceramics predominantly based on fine-grained aluminum oxide of high purity and high density for cutting-tools, gaskets, slide rings, and bone implantates. With its 52.5-percent commitment to the Feldmühle Kyocera Europa, which exclusively produces electronic components, the mother company, Feldmühle, is also linked with the Japanese ceramics manufacturer, Kyocera, holding 70 percent of the world market in ceramic cases for microchips.

In the scope of the materials research program, Feldmühle is committed to two projects. The first project concentrates on the development of ceramic construction materials of high mechanical, thermal, and corrosion-resistant qualities for application in piston engines. Objective of the project is to develop ceramic construction units, such as piston-heads, cylinder sleeves, cylinder-head covers, precombustion chambers, valve seats and guides, valve stems, bearing shells, and wrist pins for gasoline and diesel engines and to improve their quality towards the production stage. One of the priorities of the project is the insulation of piston-heads which has satisfactorily been achieved by an improvement of the stress characteristics of ZrO_2. The project is conducted in close cooperation with the motor vehicle manufacturing industry and is budgeted with DM4.4 million ($2.5 million).

The second project points to the development of soldering techniques and processes for structural ceramics and metal alloys, with focus on the achievement of ceramics qualities for direct soldering of ceramics on metal and with respect to the reproducibility of the soldering process and the reliability requirements for application in the production line of the automobile manufacturing industry. Tests are conducted with ZrO_2, Si_3N_4, SiC, and TiO_2/TiC. In the framework of this project, research and development concentrates also on the improvement of mechanical stress characteristics, such as bending strength, alternating bending strength, and life endurance. Project costs are budgeted with DM1.32 million ($0.75 million). It is carried out in cooperation with the Technical University of Karlsruhe, Degussa, and Daimler-Benz.

Daimler-Benz participates in the Materials Research Program with six projects, five of them dealing with the development of prototype construction units and one with the development of joining processes and techniques. The projects cover the development of:

- Turbine boxes for motor vehicle turbo chargers, constructed of sintered SiC
- Development and testing of ceramic gas turbine construction units, such as intermediate-diffusor rings, and compressor front and end deflector grids
- Development of construction units of the high-temperature section of gas turbines and piston engines based on sintered silicon carbide and aluminum titanate
- Development of construction units of die-cast silicon nitride
- Development of turbine wheels of ceramics materials.

The projects are carried out in cooperation with the Technical University Karlsruhe, the Max-Planck-Institute of Materials Research at Stuttgart, and GTE laboratories, US. The financial volume of these six projects amounts to DM20.6 million ($11.8 million). Hoechst-Ceramtech performs research on two similar projects dealing with the development and testing of construction elements for gas turbines based on pressureless sintered and hot-isostatic postcompression silicon nitrides. The first project comprises the development of pressureless and die-casting techniques for construction units of simple and complicated geometric shapes, investigation of suitable temperature/time process programs for the nitriding process and the hot-isostatic compression, and the research on suitable test and quality-assuring measures. The second project focuses on the development of a die-casting technique for pressureless sintered silicon nitrides and on the development of a quality-assurance system for the production stage. Both projects are budgeted with a total of DM11.75 million ($6.7 million).

Other companies involved in the BMFT Program are Degussa, Elektroschmelzwerk, SIGRI, Dynamit-Nobel, Volkswagen, Motoren-Turbinen-Union (MTU), Nukem, and some other, smaller companies for a total financial volume of approximately DM61.2 million ($35.0 million).

Institutional Research Activities

Among the large-scale research facilities committed to the Materials Research Program, are those of the main project leaders, represented through various Fraunhofer Institutes, Max-Plack-Institutes, and the Technical University of Berlin. Other research facilities, such as those of the German Aerospace Research Establishment (DLR) and universities are participating as subcontractors. While the Fraunhofer Institutes and the Max-Planck-Institute of Metal Research at Stuttgart concentrate on basic research, the Technical University of Berlin focuses more on industry-applicable research of ceramic powders processing and development of ceramic construction units.

The projects carried out at the Fraunhofer Institutes of Non-Destructive Testing of Materials (IZFP) at Saarbruecken, of Production Technology at Aachen, and of Material Mechanics at Freiburg comprise research topics on quality assurance including destructive and nondestructive material testing (as well as final treatment of ceramic construction elements at the production stage) and optimization of ceramic parts with respect to their mechanical and thermal stress and wear resistance. The Fraunhofer Institutes are involved in five projects having a total financial volume of DM6.7 million ($3.8 million).

The Max-Planck-Gesellschaft (MPG) participates in the materials research activities through its Institute of Metal Research at Stuttgart under its scientific leader, Professor G. Petzow, well-known of his high competence in materials research. The Max-Planck-Institute (MPI) of Metal Research is committed to three projects. The objective of the first project is to develop ceramic materials of high thermal and mechanical stress capacity and high reliability as a basis of high-performance construction units of combustion engines and turbines. The project comprises the development and definition of characteristics of structure-strengthened high-temperature ceramics based on silicon nitrate, aluminum nitrate, and silicon carbide of high strength, as well as of high creeping and thermal shock resistance at temperatures up to 1500°C and 2,000 hours life endurance. In addition, research focuses on the development of improved qualities of zirconium oxide ceramics concerning high strain- and wear-resistance and on the investigation of zirconium oxide as an additive to other ceramic composites acting as a hairline crack stopper. The project is divided into three priority subprojects – powder preparation, strengthening of ceramic structures, and improvement of high-temperature characteristics.

In the scope of this project, research work is performed with respect to high-purity powder production and development of various drying and casting procedures. It focuses on processes of strengthening ceramic structures via pinpointed creation of ceramic alloys including deposit of modifiable particles, elimination of structural deficiencies, devitrification of crystal grain phases, and adjustment of whiskers which are to contribute to those strengthening mechanisms like breaking strain, tensile solidity, and creeping resistance. Thirdly, it covers investigations of thermomechanical high-temperature characteristics with respect to life endurance and alternating temperature and stress cycles. The project is backed with a total of DM17.15 million ($9.8 million) with 50 percent public funding. The project is closely bound to additional self-financed research and development projects of Bayer, Daimler-Benz, Hoechst, and Motoren-Turbinen-Union (MTU) companies.

The second project concentrates on reaction-sintering processes of multicomponent silicon nitrate alloys and investigation of their high-temperature qualities. In the framework of this project, sintering processes have been carried out with Y_2O_3, Li_2O, or silicon carbide containing Si_3N_4 mixed crystal ceramics with different alpha and beta phases. Research work also includes investigations on devitrification of spodumene ($LiAlSi_2O_6$) and its thermo-mechanical qualities. This project is budgeted with DM400,000 ($229,000) and 100-percent-funded through the BMFT's Materials Research Program.

In the framework of the third project, investigations are performed on the influence of different powder refinement processes concerning improvement and reproducibility of mechanical and thermal qualities of ceramic materials. Research work has been conducted with aluminum-magnesium-spinel (Al-Mg-MgO, Al_2O_3) ceramics with zirconium oxide deposits to investigate the improvement of thermomechanical qualities. An optimization of ceramic structures has been reached with respect to homogeneous grain sizes, and grain and pore distribution through the development of a rate-controlled sintering process. The zirconium oxide deposits and the separation of aluminum oxide particles led to a considerable improvement of the fatigue strength up to temperatures of 1000°C, and of tensile strength and thermal shock resistance. The project was funded with a total of DM347,000 ($198,000) through the BMFT.

At the Technical University of Berlin, the Institute of Non-Metallic Materials and the Institute of Chemical Engineering are carrying out three projects with a total volume of DM2.7 million ($1.54 million) on the synthesis and characterization of ceramic powders for sintering processes, on the production of silicon nitride powders, and on the development of filters of silicon carbide for hot gases which are manufactured on the basis of the coatmix process.

Various other projects are carried out either individually or in close cooperation at industrial companies or research institutions. Table 5 provides the number of projects performed and the total financial volume of the projects on ceramic materials research conducted by industrial and institutional organizations. It shows a widespread spectrum of research activities which are coordinated through the Office of Project Coordination on Materials and Raw Materials Research (Projektleitung Material-und Rohstofforschung-PLR) at the Jülich Nuclear Research Facility (KFA) to prevent redundancy in research activities.

Table 5: Institutions conducting ceramic materials research work. (Source: BMFT)

Main Contractor	Number of Projects	Total Financial Volume Million DM ($) $1.0/DM1.75		Federal Funding Ratio (Percent)
Daimler-Benz	6	17.35	(9.91)	46.5
Hoechst Ceramtec	2	11.74	(6.71)	46.1
Hutschenreuther	3	9.10	(5.20)	48.3
Feldmühle	2	5.71	(3.26)	42.3
Elektroschmelze	3	16.03	(9.16)	47.8
Friedrichsfeld	2	4.16	(2.38)	45.7
Degussa	2	9.15	(5.23)	50.0
Sigri GMBH	2	12.76	(7.29)	46.7
Lonza-Werke	2	2.22	(1.27)	50.0
Brown, Boveri	1	7.53	(4.30)	50.0
Dynamit-Nobel	1	0.75	(0.43)	50.0
MTU	1	1.18	(0.67)	40.0
Nukem GMBH	1	7.76	(4.43)	50.0
Volkswagen	1	2.34	(1.34)	40.0
Basalt GMBH	1	3.40	(1.94)	50.0
Cremer Forschung	1	1.41	(0.81)	40.0
G + P Motoren	1	0.73	(0.42)	40.0
Krone Messtechnik	1	1.89	(1.08)	50.0
Schott Glaswerke	1	1.86	(1.06)	50.0
Seilstorfer GMBH	1	0.59	(0.34)	50.0
H.C. Stark Berlin	1	0.53	(0.39)	40.0
Th. Heimbach GMBH	1	0.80	(0.46)	50.0
Fraunhofer Gesellschaft FHG	5	6.71	(3.83)	59.8
Max-Planck Gesellschaft MPG	3	17.91	(10.23)	52.1
Technical University Berlin	3	2.69	(1.54)	86.2
University Karlsruhe	3	1.54	(0.88)	82.6
University Clausthal	1	0.30	(0.17)	100.0
Total	52	148.14	(74.65)	50.4

NEWS, NOTES, AND ABSTRACTS

REPORTS ON EUROPEAN SCIENCE AND TECHNOLOGY FROM OTHER COMMANDS

Reports

Information on each of the reports listed below was furnished by the activity identified by the abbreviations for that office. Report numbers are given in brackets after the titles. Requests for copies of or information about the reports should be addressed to the appropriate office (unless otherwise indicated):

USARDSG – US Army Research Development and Standardization Group, Box 15/65, FPO New York, 09510-1500

EOARD – European Office of Aerospace Research and Development, Box 14, FPO, New York 09510

Computer Science

Distributed Light Weight Processes in MOS, by Amnon Barak and Dalia Malki, Department of Computer Science, The Hebrew University of Jerusalem, a report on research funded in part by the US Air Force Office of Scientific Research. [Available through the Defense Technical Information Center (DTIC)]

This paper describes the Distributed Light Weight Processes (DLWP) mechanism, a facility for supporting distributed programs in MOS, a multicomputer operating system (BaL85). The goal of the DLWP mechanism is to be able to exploit concurrency in a distributed environment. The mechanism is designed to be able to support a variety of application types by supporting processes as a programing tool. It exploits concurrency up to the level available in the system and provides additional, virtual concurrency through time sharing. In this way, it can be used both for efficient utilization of concurrency and for experimenting with large-scale concurrent programs.

The DLWP mechanism is implemented immediately above the operating system kernel level, in the form of a user-level runtime library. It extends the uniprocessor Light Weight Processes (LWP) mechanism through a new operation, *split*, which adapts the classical LWP mechanism for distribution and dynamically disperses the workload among processors. A LWP pod within a Heavy-Weight Process (HWP) may split to create multiple pods that execute in different HWP's. The MOS dynamic load balancing (BaS85) automatically assigns the HWP's to different machines and provides concurrency.

The partitioning strategy takes into consideration past behavior of the LWP's, in terms of CPU consumption and communication. This profile information is used to reach a partition that splits the load evenly while incurring minimum communications overhead. For this purpose, the profile information is kept in a graph and a heuristic graph-partitioning algorithm is employed.

A Holographic File System for a Multicomputer with Many Disk Nodes, by Amnon Barak (The Hebrew University of Jerusalem), Bernard A. Galler (University of Michigan), and Yaron Farber, (The Hebrew University of Jerusalem), a report on research funded in part by the US Air Force Office of Scientific Research. [Available through the Defense Technical Information Center (DTIC)]

Future computing systems may involve thousands of networked general-purpose computers, without shared memory or shared devices. The "operating system" for such a configuration must be completely distributed, and it must tolerate the random disappearance and reappearance of nodes, possibly with obsolete control information and/or data. Traditional file systems are not equipped to satisfy these requirements.

This report presents a "holographic" file system (HFS) for concurrent data retrieval in a computer system with a large number of disks (although it is probable that most nodes will be diskless). In such a file system it is possible to operate on a file by simultaneously utilizing many (or all) of the disks, since the file system is organized to take advantage of the multiplicity of equipment, rather than limiting access to a single disk for each file, as in most existing file systems. The main advantages of the HFS are a speed-up in data retrieval related to the number of disks, and improved availability by allowing access to parts of a file even when other parts of that file are not accessible.

Visit to Institute of Applied Physics, University of Erlangen, West Germany, by Dr. J. Zavada, USARDSG.

Dr. Zavada visited the University of Erlangen and met with Professor Max Shulz, who is head of the Institute of Applied Physics. Professor Shulz presented an overview of the university research programs in the area of solid-state electronics and on the university's structure in general. During a tour of the institute, Professor Shulz explained details of the various experiments currently in progress. In particular, he described details of his work concerning transient spectroscopy of individual interface traps in field effect transistors. This work has important consequences on the design and operation of microelectronic circuits, and Professor Shulz has developed a very concise model for interpreting the experimental results. In FY88 Shulz visited the US Army Electronic Technology and Devices Laboratory and briefed them on some of his results. He is continuing research in this and other areas relating to solid-state electronics. As a result of a large grant from the State of Bavaria, Shulz will be moving the institute into a new building early in 1989. While the present location of the institute is adequate for the research experiments being conducted, the new building and more modern equipment will enhance the overall capability of his group.

Mathematics

Research on Statistical Inference of Stochastic Processes, by Dr. G.R. Andersen, USARDSG.

Dr. Andersen, Chief of the ERO Mathematics and Physics Branch, met with mathematical statisticians at universities in Denmark and Norway. These scientists – Per Kragh Andersen, Statistical Research Unit, and Martin Jacobson, Institute of Mathematical Statistics of the University of Copenhagen; Odd Aalen, Section of Medical Statistics, and Ornulf Borgan, Institute of Mathematics of the University of Oslo – are part of a group, primarily from the Scandinavian countries, Finland, and the Netherlands, who have worked together to produce a theory in inference for counting processes. Their aim has been to develop statistical models for life history data based on counting processes (e.g., survival analysis or failure time analysis). Although this subject has a long history, the 1975 thesis of Odd Aalen, obtained at the University of California at Berkeley, provided a fundamental breakthrough utilizing the then newly developed general theory of stochastic processes (semimartingales and stochastic integration) that resulted in a unified and general analytic framework based on counting processes in which censored failure time data could be studied. He also showed that classical failure models had the multiplicative intensity structure that he introduced. During the next 10 years his methods were taken up and utilized by the extremely talented group of scientists alluded to above in order to extend numerous methods from the survival analysis literature and to begin a rigorous and complete development of a theory of inference for statistical models based on a multivariate counting process. As a result, this group (together with R.D. Gill of the Center for Mathematics and Computer Science, Amsterdam) have become world leaders in the development and application of statistical models for censored failure time data. These models are far more general than those usually applied in Army system reliability studies.

Performance Evaluation of the MOS Distributed System, by Richard Wheeler, a thesis submitted towards the degree of Master of Science, Institute of Mathematics and Computer Science, the Hebrew University of Jerusalem. This work was funded in part by the US Air Force Office of Scientific Research. [Available through the Defense Technical Information Center (DTIC)]

The MOS system is an integrated multicomputer system which was designed to preserve the standard UNIX interface while providing complete network transparency. This thesis measures and analyses the performance of the internal mechanisms of the system, including all of the system calls, interprocess communication mechanisms, and process migration. Several distributed application programs, the most successful of which show an almost linear improvement in performance as the number of processors increases, are also analyzed.

Theory and Application of Random Fields, by Robert J. Adler, Faculty of Industrial Engineering and Management, Technion-Israel Institute of Technology, a final scientific report on research funded in part by the US Air Force Office of Scientific Research. [Available through the Defense Technical Information Center (DTIC)]

The main results discussed in this report include:

1. The modeling of rough surfaces via Gaussian and non-Gaussian random fields. Development of new classes on non-Gaussian random processes.
2. The distributional properties of the suprenum of Gaussian random processes defined on general state spaces. Applications of these results to the theory and application of empirical processes.
3. Investigation and development of the interface between Gaussian and Markovian processes. Results on local time and intersection local time of measure and distribution valued processes.
4. Preparation of a monograph treating the general theory of continuity and boundedness for Gaussian processes via entropy and majorizing measures.

THE EMBASSIES: TECHNOLOGY ROUNDUP

European Communities (EC)

For further information on EC items, contact Ms. Patricia Haigh, US Mission to the European Communities, American Embassy, APO New York 096671000.

EC Adopts Pilot Program on Aeronautical Research and Development. On December 15, the EC council of (research) ministers approved a 2-year pilot program for precompetitive research and development in aeronautics. The program will commence in 1989 and be funded at 35 million ECU (about $41 million) for the 2-year period. The funding will come from allocations to the community's BRITE/EURAM program (for industrial technologies and advanced materials), although the aeronautical program was developed independently of that program.

Notably, the program now includes only four of the seven research categories identified in the original commission proposal – i.e., aerodynamics, acoustics, airborne systems and equipment, and propulsion systems. Two of the remaining three categories – materials and design and manufacturing technology – have been folded into the BRITE/EURAM program. The other – computation – was integrated into the four categories in the adopted proposal. Since the number of identified categories has decreased, the funding amount proposed by the commission (60 million ECU) has been decreased to 35 million ECU.

According to EC commission official Herbert Allgeier (of the Directorate-General for Science, Research, and Development [DG-XII]), Ireland's initial opposition to the program, based on a fear that it would contribute to the development of military aircraft, was overcome by arguments from the commission. The UK and Denmark opposed the extension of the BRITE/EURAM Program into aeronautical R&D; both countries abstained during the council's vote.

The commission continues to deny that there is a linkage between the aeronautical R&D program and the current dispute between the US and the EC over alleged subsidies to airbus industries.As reported previously, the pilot program is a precursor to a 2-year program scheduled to begin in 1991. However, the focus and funding of that subsequent program would depend on the success of the pilot project. The pilot program will "twin" research efforts of two or more companies or research facilities in two or more member states in the identified areas of research. Fifty percent of the funding of the research will be provided by the EC, the other 50 percent will be provided by the companies.

EC Commission Publishes Industry Study Used to Formulate New Aeronautical R&D Program. The EC Commission recently announced that it would make public the "EUROMART" report requested and used by the Commission during the development of its new aeronautical R&D program. The report – known formally as the "European Cooperative Measures for Aeronautical Research and Technology Report" – was drawn up by the community's major aeronautical companies, i.e., Aeritalia, Aerospatiale, Avions Marcel Dassault-Bréguet Aviation, British Aerospace, CASA, Dornier, Fokker, Messerschmitt-Bölkow-Blohm, and SABCA.

The findings of the report, not surprisingly, are very similar to the rationale used by the commission in its development of the Aeronautical R&D Program. The European industry has reason to be concerned about its future despite the accomplishments of recent years. Its global competitive position is threatened by the technological efforts in the US, Japan, and the newly industrialized countries. The world market is expanding and will continue to develop, but competition will become increasingly severe. An energetic program of technological R&D should be implemented at the community level.

France

For further information on French items, contact Dr. Allen Sessoms, Office of the Science Counselor, American Embassy, APO New York 09777.

The Most Innovative Firms in France. In a recent dossier on innovations in France, the French newspaper *Le Monde* listed the most innovative firms in France in 1987 by R&D expenditure. The top 25 most innovative firms in France by R&D expenditure are shown in Tables 1 and 2.

Le Monde emphasizes that the 1987 R&D expenditure of the top 25 most innovative firms increased by an average of 9.2 percent. In comparison, the 1986 R&D expenditure increased by 8 percent. Another interesting fact is that the turnover of the 25 firms increased by 6.6 percent. This implies that these corporations earmark a greater fraction of their turnover for R&D. However, in 1987, the profits of all quoted French firms increased by 18 percent. This leads *Le Monde* to conclude that profits still take precedence over research.

Le Monde also points to the boom in the number of projects developed within the EUREKA framework or within EC programs. CGE and Thomson participate in over 50 programs, Bull in over 30. The success of the Europe of research cannot be denied, according to *Le Monde*. However, the newspaper indicates that it nevertheless remains relative in that the majority of the projects are in electronics, while chemistry and pharmacy remain weak.

The Medical Research System in France – the Conclusion of a Report. The conclusions of the report, prepared by the Paris Embassy on the Medical Research System in France are detailed in the following paragraphs.

France has the human resources to conduct excellent biomedical research. France is one of the leaders in AIDS research – not to mention that eight French researchers have been awarded Nobel prizes in the biomedical field. The difficulties encountered by France do not lie in the quality of French biomedical research, but in the organization of a system which is basically bureaucratic and administratively oriented. While the French government tends to plan and centralize, the US government, by contrast, tends to coordinate and orient. The paradox is that French planification and centralization generate rigidity but do not prevent overlaps and rivalries. Whether these preserve competitiveness or contribute to wasting funds, energies, and ideas – especially in a country the size of France which may not be able to afford internal divisions – remains open to debate.

Table 1. The top 25 most innovative firms by R&D expenditure.

Rank 1987	Rank 1986	Companies	Sector	R&D Expendit. in thousand FF ($ thousand) 1987	R&D Expendit. in thousand FF ($ thousand) 1986	Number of Empl. in R&D in 1987
1	3	CIE Générale D'Electricité	Energy, Communications	10,000 (1,667)	5,500 (917)	16,280
2	2	Aérospatiale	aeronautics	7,835 (1,306)	7,326 (1,221)	9,950
3	1	Thomson	electronics	6,600 (1,100)	7,800 (1,300)	7,680
4	7	Peugeot SA	automobiles	3,900 (650)	2,700 (450)	
4	5	Renault	automobiles	3,900 (650)	3,550 (592)	7,300
6	4	SNECMA	aeronautics	3,826 (638)	3,554 (592)	6,234 6,234
7	6	Rhône-Poulenc	chemistry, pharmacy	3,517 (586)	2,954 (492)	8,000
8	7	ELF Aquitaine	oil, chemistry	2,700 (450)	2,700 (450)	3,930
9	9	Michelin	pneumatics	2,500 (417) (Estimated)	2,360 (393)	3,500
10	12	Matra	electronics, transportation	2,230 (372)	1,600 (267)	
11	10	Bull	computers	2,035 (339)	1,842 (307)	3,400
12	11	Philips (France)	electronics	1,472 (245)	1,520 (253)	3,556
13	13	Roussel UCLAF	pharmacy	1,218 (203)	1,175 (196)	2,000
14	15	Saint-Gobain	glass, cast iron, wood	1,042 (174)	996 (166)	2,456
15	15	L'Oréal	cosmetics	1,020 (170)	995 (166)	
16	21	Electronique Dassault	electronics	975 (162)	640 (107)	2,200
17	19	Péchiney	metallurgy	808 (135)	720 (120)	1,500
18	18	USILOR Sacilor	iron & steel metallurgy	700 (117)	730 (121)	1,300
19	22	Air Liquide	industrial gas	690 (115)	630 (105)	900
20	20	Total	oil	600 (100)	593 (99)	813
21	24	ORKEM (Formerly CDFChimie)	chemistry	334 (56)	325 (54)	828
22		Shell France	oil, chemistry	310 (52)	305 (51)	828
23		EMC	chemistry	154 (26)	147 (24)	358
24		ESSO France	oil	83 (14)	89 (15)	133
25		Vallourec	metallurgy	81 (13)	68 (11)	250

Table 2. The top 25, showing total turnover, number of employees, and European programs.

Rank 1987	Companies	Turnover in thousand FF ($ thousand) 1987	1986	Number of Employees 1987	Participation in European Programs (No. projects)
1	CIE Générale D'Electricite	127,500 (21,250)	80,500 (13,417)	219,000	52
2	Aérospatiale	31,361 (5,227)	33,845 (5,641)	36,900	10
3	Thomson	60,200 (10,033)	62,650 (10,442)	86,000	53
4	Peugeot SA	118,167 (19,694)	104,946 (17,491)	160,600	Yes (number not known)
5	Renault	147,500 (24,583)	134,900 (22,483)	182,800	22
6	SNECMA	15,123 (2,520)	15,402 (2,567)	25,600	Yes (number not kown)
7	Rhône-Poulenc	56,160 (9,360)	52,694 (8,782)	82,500	8
8	ELF Aquitaine	127,400 (21,233)	119,700 (19,950)	73,000	None
9	Michelin	46,936 (7,823)	46,328 (7,721)	117,000	Yes (number not known)
10	Matra	17,200 (2,867)	14,450 (2,408)	19,000	16
11	Bull	18,071 (3,012)	17,796 (2,966)	26,340	35
12	Philips (France)	21,491 (3,582)	20,502 (3,417)	28,750	24
13	Roussel UCLAF	9,683 (1,614)	9,850 (1,642)	14,786	1
14	Saint Gobain	78,887 (13,148)	77,727 (12,954)	131,324	9
15	L'Oréal	20,095 (3,349)	18,130 (3,022)	26,860	None
16	Electronique Dassault	3,712 (619)	3,173 (529)	4,200	3
17	Péchiney	38,947 (6,491)	34,667 (5,778)	47,426	17
18	USINOR Sacilor	67,000 (11,167)	72,300 (12,050)	79,800	22 (CECA)
19	Air Liquide	23,460 (3,910)	20,959 (3,493)	26,000	2
20	Total	87,087 (14,514)	95,722 (15,954)	40,500	7
21	ORKEM	20,000 (3,333)	23,000 (3,833)	16,600	None
22	Shell France	35,737 (5,956)	36,676 (6,113)	6,938	Yes (number not known)

Even though the situation is rapidly improving, the weakness in France in insuring the industrialization and marketing of innovations is an even more acute problem. Whether in pharmaceuticals or biological and medical engineering, research institutions are very active and research is excellent, but French industry does not always follow suit, particularly in biological and medical engineering. As a result, public research institutions grant licenses to foreign industrialists which bring income to the former but, in the long run, jeopardize French trade balance. French scientist Louis Pasteur founded microbiology. However, in 1984, the No. 1 world producer of enzymes and the No. 2 producer of antibiotics was Japan rather than France. France's contributions to modern immunology are numerous. One of the best examples is the French Scientist Jean Dausset's works on cellular immunology, for which he was awarded the Nobel prize in 1980. However, a majority of foreign and not French firms occupy the French market for the commercialization of immunology reactives. This reflects an ongoing problem in France which simply does not exploit its commercial structure in order to become competitive. This is true not only in pharmaceuticals and biological and medical engineering but in many industrial sectors as well. Therefore, it is vital for France not only to improve interaction between the public and private sectors but also to establish a strong commercial structure. Another very urgent problem to be resolved is the scientific education of clinicians. New strategies must be found not only to train clinicians but also to coordinate health care, research, and teaching and eliminate the barriers between the medical and scientific worlds. Both clinicians and scientists must be able to speak the same language to be able to collaborate.

Finally, French and US employment policies are quite different. In the US, teams begin and end with their contracts and therefore depend on the science market. In France, employment stability is guaranteed. The US system may not be transposable in France if only for sociological reasons. People do not accept a move so easily. However, to compensate for the relative lack of flexibility of the French system, it is important that a coherent employment policy be defined that provides for the recruitment of younger researchers and permits brainstorming. If France wants to be in a position to meet the European challenge in 1992 which will increase competition and therefore reveal France's weaknesses, it is important that measures be taken to reinforce France's position. The fact that research has become one of the priorities of the French government which, inter alia, has allocated funds to boost industrial research and also recruit researchers, is a positive sign that France is intent on preparing for 1992 and on facing an expanded market which may – and most likely will – augment researchers' movements and reinforce the impact of R&D.

Italy

For further information on Italian items, contact Mr. Gerald J. Whitman, Office of the Science Counselor, American Embassy, APO New York 09794.

First Italian Consortium for Informatics Formed. IRI, ENI (National Hydrocarbons Agency) and EFIM (Agency for Manufacturing Industry Financing) have joined their informatics companies (G.I., Enidata, and Efimdata) to provide the Ministry of State Holdings with an advanced informatics system development capability. The project, worth 15 billion lire (about $11 million), is part of a project to consolidate Italy's informatics industries to meet the challenges of the 1992 liberalized European market.

Construction of Trieste Synchrotron Underway. Construction of the "third generation" synchrotron is presently underway at the Trieste research area. When completed in 1991, the 260-meter-circumference device will make available to government and industry researchers synchronized light in the X and ultraviolet regions "unparalleled for quality and brilliance," according to Nobel Laureate Carlo Rubbia. Several research organizations, including Zurich Polytechnic, the Austrian University of Graz, and the University of Wisconsin, are among those applying for access to the facility. The consortium of the Trieste Research area, the regional administration of Trieste (Venezia Giulia) and the Italian National Research council (CNR) are investing 45, 30, and 75 billion lire (about $34, 22, and 56 million) respectively for the synchrotron's construction.

ENEL Plans Offshore Electricity Production. ENEL, the Italian electricity agency, is conducting a feasibility study to build electricity generating platforms offshore. The first of these islands would be located just outside Italian territorial waters – 20 to 30 kilometers in the northern Adriatic Sea. The platforms, measuring 750 by 550 meters, provide space for four 660-MW multifuel powerplants operating on methane gas, coal, or oil, and permanently manned by about 600 people. The cost of a prototype is estimated at 6,000 billion lire (about $4.8 billion) – producing electricity at 16 lire per kW/hr (about 1.3 cents) higher than that produced by traditional landbased plants. ENEL plans to award the first construction contract no later than June 1989. (Comment: Italian environmentalists strongly oppose the offshore scheme, despite ENEL's assurances that pollution devices will control harmful emissions).

Fuel Cell Powerplant in Operation by 1990. The Italian agency for nuclear and renewable energies (ENEA) will build in Milan a 1-MW experimental fuel cell powerplant, the largest in Europe. The experimental plant will be ready in Milan by the end of 1990 and will cost 40 billion lire (about 30 million dollars). In addition to ENEA, Ansaldo and the Milanese Electric Company will participate in the project, with some support from EEC. ENEA is also constructing two small fuel cell plants (25 kW each) in Rome and Bologna which should be operating in 1989 and 1990.

Environmental Institute Created by Industries in Milan. The President of the Italian Industry Association (CONFINDUSTRIA), announced that the organization will sponsor the creation of an institute for studying the environment. The institute will commence operating in Milan the beginning of 1989 with an initial financing of 5 billion lire (about $4 million) per year. The institute will advise industry on environmental issues, helping firms rebut charges of industrial pollution. The institute will have the support of the four Milan universities.

Mediterranean Remote Sensing Center Established. Telespazio will commence operation of a remote sensing center to study the Mediterranean marine environment, using the facilities of Italy's space telecommunications in Scanzano, Sicily. The center is the Italian contribution to the UNEP program for the protection of the Mediterranean provided for by the Barcelona Convention.

New Ocean Transport Technologies Explored. The shipbuilding research organization, CETENA, and the Research Center of the Fincantieri Group are initiating cooperation with Italy's shipbuilding industry to explore new ocean transport technologies. The projects include: a new generation of hydrofoils using high-pressure Oleodynamic Propulsion Engines; a special electrical vessel for public transportation in Venice that employs rechargeable batteries and results in a 20-percent energy saving and less wave damage to palaces; and an amphibian boat destined for swampy terrain and able to be used for natural disasters.

United Kingdom

For further information on British items, contact James Devine, Office of the Science Counselor, American Embassy, London, APO New York 09509.

Breakthrough in Electron Beam Small Writing. In December 1988, Professor William Mitchell, Chairman of the Science and Engineering Research Council (SERC), announced that the world's smallest writing had been achieved by a new electronic beam technique. The new technique opens the way for machining with the highest precision and creating the fastest electronic circuit. According to Mitchell, the potential for information storage is one thousand times better than anything currently available – the instrument is capable of writing the entire content of the 29 volumes of the Encyclopedia Britannica on a pinhead.

The project was carried out at Liverpool University using a powerful electron microscope. Funded from the SERC's £357 million (around $640 million) research budget, it was "an unexpected discovery" by Professor Colin Humphreys. It is possible to write one million lines side by side in the width of a pencil line, using an electron beam from the electron microscope, or drill one million million holes on the head of a pin.

By drilling an array of holes in a given pattern, information can be stored in a similar way to that used for piano rolls which store music for a pianola to "read." Humphreys said uses for the huge storage capacity were already being put forward. Interestingly, New Scotland Yard had asked if the technique could store photographs of criminals.

The "beam writer" can make filters for molecules and viruses. Other uses include making ultrafine, and ultrafast, electronic circuits and making templates for molecules. The templates could be used to control the way molecules crystallize, in what Humphreys called "molecular engineering."

West Germany

For further information on West German items, contact Mr. Edward Malloy, Office of the Science Counselor, American Embassy, APO New York 09080.

DFVLR Becomes DLR. In a personal letter, the Chairman of the Directorate of the German Aerospace Research Establishment, Professor Dr. Walter Kroell, has informed the Science Counselor that the German Aerospace Research Establishment (Deutsche Forschungs-und Versuchsanstalt für Luft- und Raumfahrt [DFVLR]) will adopt under a slightly modified name.

The future German name will be: Deutsche Forschungsanstalt Für Luft- und Raumfahrt (DLR).

In English, we shall continue to use the familiar name, "German Aerospace Research Establishment" – now an exact translation of the new German name. Only the abbreviation will change from DFVLR to DLR.

Establishment of German Radiation Protection Agency. On 7 December 1988, the West German cabinet decided to establish an independent Federal Radiation Protection Agency in this coming July. The new agency will employ a staff of 400. According to the cabinet's decision, the Institut für Strahlenhygiene (Institute for Radiation Investigation) and the Institut für Atmosphaerische Radioaktivität (Institute for Monitoring of Atmospheric Radioactivity) will be taken over by the new agency. The Institute for Radiation Investigation at Neuherberg (in the vicinity of Munich) currently operates as a subdivision of the

Federal Health Agency in Berlin; the Institute for Monitoring of Atmospheric Radioactivity near Freiburg is an independent institute operated by the Federal Ministry of the Interior (BMI) to coordinate emergency preparedness measures.

The new agency will be tasked with the following:

- Construction and operation of final repositories for radioactive wastes
- Licensing of intermediate fuel storage and transportation of nuclear fuels
- Monitoring and control of radioactivity in the environment by means of an integrated measuring and information system
- Development of a standard of radiation exposure doses for the protection of personnel
- Advising the Federal Ministry of Environment, Nature Conservation and Reactor Safety (BMU) on all matters related to radiation protection, nuclear safety, and nuclear waste management.

Fine Superconductor Coating. A new procedure for the production of extremely fine films of high-temperature superconductors has been developed by members of the Institute for Coating and Ion Technology of the Nuclear Research Installation at Jülich (Kernforschungsanlage [KFA]). By application of a highenergy laser beam, the scientists vaporize superconducting yttrium-barium-copper oxide from the surface of a probe. The vaporized atoms are released vertically and meet upon the substrate to be coated, which can be heated in an oven up to 1000°C. By turning the probe, the superconductor can be released evenly. The new method is especially fast – in only 5 minutes the film can be applied to a substrate. No time-consuming aftertreatment is necessary. The films released upon strontium-titanium-oxide become superconducting at 92 K and carry energy densities of more than 1.5×10^6 A/cm^2. The superconducting fine films can be used for the wiring of semiconductor elements, reducing the heat development in computers.

Superconducting Generator. In November, Siemens AG at its Mülheim facility, presented a generator with superconducting field winding to German and foreign energy supply enterprises. This was the first public representation of a test rotor with superconducting field winding with a construction size of 400 MVA. It is the first step of a new prototype rotor for an 850-MVA generator, which is to be tested in the 1990's. In comparison with conventional generators with equivalent efficiency, the advantages of the new generator type are lower investment costs and more favorable operational properties.

Solar Energy. A "historic event in energy production" took place recently with the inauguration of the first photovoltaic installation, located at Kobern-Gondorf, according to the Chairman of the Rheinisch-Westflälische Elektrizitätswerke AG (RWE) at Essen. The installation is directly connected with the energy network of RWE and with a 340-kW capacity is the (so far) largest solar cell installation in Europe.

The direct current produced by the solar cells is transformed by inverters directly into alternating current – without intermediate storage in batteries – and via transformer fed into the network. The installation, in its first construction stage, was established at a cost of DM13 million (about $7.2 million), of which the state of Rhineland-Palatinate contributed 10 percent. The installation should provide annually about 250,000 kWh of electricity into the RWE network, of which 75 percent will be produced during the summer months.

Max-Planck-Institute for Informatics. Reflecting the priority that the federal government accords advanced computer systems, the Max-Planck-Society has decided upon the establishment of a new Institute for Informatics at Saarbruecken. The institute will be headed by Professor A. Nico Habermann of Carnegie-Mellon University at Pittsburgh. Eventually, the institute is expected to house 80 employees, of whom 60 will be scientists.

The new institute will focus on research into large-scale computer systems – i.e., parallel algorithms, program languages for parallel systems, instrumentation for system programing, and hardware architecture for massive parallel systems. One of its fields of activity will be application orientation, e.g., for numerical simulation, a field in which construction problems will be investigated in cooperation with industry and other research institutions.

Siemens US Research Center. In mid-October 1988, Siemens AG opened its own research center at Princeton, New Jersey. Approximately 150 members will be employed there under the worldwide Siemens Research Program on fabrication automation, language recognition, expert systems, and other advanced software technology. In addition to in-house research, the center, established at a cost of $26 million, will support the 35 other development centers which Siemens operates in the US and also will improve cooperation with American universities. As announced at the inauguration of the center, at present, there are joint research projects in the total amount of $2.5 million.

Cooperation in Materials Research. An agreement for cooperation in research in high-efficiency ceramics was concluded by the University of Stuttgart, the Max-Planck-Institute for Materials Research, and the Feldmühle AG at Düsseldorf. A new institute for nonmetallic anorganic materials (high-efficiency ceramics) will be established at the University of Stuttgart, with a financial contribution not to exceed DM100,000 (about $44,000) per annum for the next 5 years by the Feldmühle AG. In addition, the Feldmühle AG will send one of its high-ranking scientists in the field of ceramics research to the institute, for 1-year periods. Within this cooperation, the Max-Planck-Institute for materials research in Stuttgart will also be included.

The Feldmühle AG has been active for the last 30 years in the field of technical ceramics and in 1988 expects a total turnover of DM 400 million ($220 million) in this field.

Research and Development by Chemical Industry. According to the Federal Association of Employers in Chemical Industry, the chemical industry expended DM8.9 billion (about $4.9 billion) in 1987 on research and development – or one-fifth of the total industrial R&D support. The chemical industry finances 96 percent of its R&D While R&D expenditures as well as the number of R&D personnel are higher in Japan and the US, related to the turnover, West German chemical industry has the highest quota of R&D expenditures.

An international comparison for R&D chemical industries in 1985 follows:

	Billion DM	Turnover Percentage
West Germany	7.9	5.3
France	4.4	4.7
Great Britain	3.5	4.6
Italy	2.0	2.6
Total Western Europe	26.5	4.5
Japan	8.6	3.5
US	21.0	4.5

Research on the Atmosphere and the Hydrosphere. The German Research Society (Deutsche Forschungsgemeinschaft [DFG]) has established a priority program "physical methods of remote sensing in the atmosphere and hydrosphere." Under the program, scientists will survey the atmosphere to an altitude of about 100 km as well as ocean and land surfaces. Five special areas will receive priority: convective water vapor transport over vegetation; development of high-reaching cumulonimbus clouds and their precipitation; exchange between stratosphere and troposphere; transport in the medium atmosphere; and relation between microwave and water sources. The projects carried out are intended to serve as pilot projects for the upcoming international geosphere-biosphere program.

New Welding Technology for Ceramics and Metals. A new welding technique, called friction welding, has been developed by members of the Fraunhofer Institute for Applied Materials Research at Bremen in cooperation with scientists of the firm KUKA Welding Technology and Robots at Augsburg. The technique is designed to permit large-scale production of ceramic-metal compound materials for use in machine and motor construction. The technology works on the basis of rotation of one part of the component, while the other is firmly fixed to the machine. The two surfaces are heated up by friction and consecutively compressed, resulting in a firm compound after only 10 seconds. So far, this technology has been used for welding of parts made out of aluminum alloy or aluminum oxide with zirconium oxide ceramics.

German Company Founded for Marketing of European Hermes Space Shuttle. The German firms Messerschmitt-Bölkow-Blohm (MBB), GMBH, the Dornier GMBH, the AEG AG, the Ant Nachrichtentechnik GMBH, and the Man Technologie GMBH have founded the Deutsche Hermes GMBH, located at Oberpfaffenhofen, near Munich.

The new firm has been founded to represent German companies participating in the development and construction of the European Hermes space shuttle, to promote the marketing of the German contribution to the development of the Hermes project, such as the development of the life systems of Hermes, to manage the preparatory phase of operation of the space shuttle, and to support German firms in the management of their tasks.

The capitalization of the new company is only DM100,000 ($57,000). MBB holds 39 percent and Dornier 28 percent, AEG AG, Ant Nachrichtentechnik GMBH, and Man Technologie GMBH hold 11 percent each.

Manager general of the Deutsche Hermes GMBH will be the Physicist Diplom-Physiker Juergen Bach, who has represented the Dornier Enterprise in Paris.

Overseas Travelers

Notes on trip reports to locations in Europe and the Middle East which have been received by ONRL are reported below. For details, contact the traveler directly.

Acoustics

Traveler: Mr. B.E. McTaggart, Transducer and Arrays Division, Naval Underwater Systems Center, New London, Connecticut.

Mr. McTaggart attended the "Second International Conference on Giant Magnetostructive and Amorphous Alloys for Actuators and Sensors." This meeting was organized by Sensglas Terfenol AB, a Swedish firm, and Edge Technologies, Inc., a US firm, both of which have been promoting the use of Terfenol in practical applications. The meeting was held at the Hotel Don Carlos in Marbella, Spain, in October 1988.

Terfenol is an example of a highly magnetostrictive alloy that was first developed by Dr. A.E. Clark, working at the US Naval Surface Weapons Center in White Oak, Maryland. For acoustic applications the material has been suggested as useful in sonar transducers and as acoustics for low-frequency active vibration control.

Judging from the list of speakers and paper titles from the conference there seems to be interest in the applications of this material throughout Europe and the UK. There were papers presented by individuals from the UK, West Germany, Sweden, France, Spain, Japan, and of course the US, where Terfenol was first developed.

While in the UK McTaggart also visited Plessey Naval Systems, at Templecombe, and the British Aerospace Corporation Undersea Technology facilities at Weymouth and Bath. At Plessey, he was briefed , in particular, on the fiberoptic sensors for underwater applications. Plessey has developed a fiberoptic hydrophone array which, in some situations, might be an attractive alternative to an array based on piezoelectric technology. [The Plessey application and more details on this can be found in MAS Bulletin MASB 59-88, dated 29 August 1988.]

During his visit to British Aerospace Underwater Systems Division, McTaggart was briefed on the Active Towed Array Sonar (ATAS) which they have developed for ASW operations. This system is a hybrid of a variable depth sonar and a passive towed array. The system consists of a receiver array, that can be deployed somewhat remote from the towing platform, and a low-frequency acoustic transmitter. Port/starboard ambiguity is resolved within the system itself, eliminating the need for ship maneuvering. Further information on the system is available from British Aerospace plc, Dynamics Division, FPC 211 P.O. Box 5, Filton, Bristol BS12 7QW, England.

Physics

Traveler: Dr. A.E. Robson, Plasma Physics Division, Naval Research Laboratory, Washington, DC 20375-5000.

Dr. Robson spent 4 days in intense discussion with the I.C. theory group at Imperial College, London, on the problem of stability of the dense z-pinch. He says that the most active investigator is Dr. Michael Coppins, who leads a group of post-docs and students working on various aspects of the problem. Robson proceeds to give brief descriptions of the work of the various involved investigators.

Robson stopped for 1 day at the Culham Laboratory and had a discussion with David Halby, who is leading a new program on the production of high-power microwaves from relativistic electron beams, then proceeded to Nice, France, to attend the "Z-Pinch and Plasma Workshop," held on 10 and 11 October 1988.

Eight papers of a plasma focus were given at the workshop; six papers on Z-pinch experiments; and nine papers on Z-pinch theory. Robson briefly summarizes the papers and states that the Proceedings of the workshop may be obtained from B Etlicher, Laboratoire de Physique des Milieux Ionises, Ecole Polytechnique, 91128 Palaisau, France.

Traveler: Dr. Warren E. Pickett, Complex Systems Theory Branch, Condensed Matter and Radiation Sciences Division, Naval Research Laboratory, Washington, D.C. 20375-5000.

Dr. Pickett attended the International Symposium on the Electronic Structure of High T_c Superconductors, held in Rome, Italy, in October 1988.

Pickett says that the meeting "was dominated by experimental presentations, with theoretical perspectives being presented by a few representatives..." The symposium session titles were: electronic structure and photoemission, optical properties, dynamics, XANES-EXAFS, x-ray emission, NMR, magnetic interactions, and theory.

Pickett's report identifies the subjects and authors of a large number of the papers presented, and makes brief comments about many of them.

After the conference concluded, he proceeded to the Institut für Theoretische Physik II at Westfalischen Wilhelms-Universität, in Münster, West Germany, where he discussed the theory of phonon spectra in crystalline solids with Dr. Claus Falter and Professor W. Ludwig, who have done much recent work in this area.

Space Sciences

Traveler: Dr. Francis J. Kelly, Ionospheric Effects Branch, Space Sciences Division, Naval Research Laboratory, Washington, D.C. 20375-5000.

Dr. Kelly attended the Annual Meeting of the International OMEGA Association, held in Munich, West Germany, in October 1988. OMEGA is a very low-frequency (10.2 kHz)) radio navigation system that uses eight widely separated transmitters on the earth's surface. It is the only full-time, whole-earth navigation systems in existence.

Issues discussed during the first 4 days of the conference were largely related to use of the system, its shortcomings, and proposals for improvement in its accuracy.

The scientific/technical session took place on the fifth and last day. Professor K. Taguchi (Kagoshima University) described observations of "cycle jumps" on the 10.2- and 11.3-kHz OMEGA signals during nighttime for south-to-north paths from the OMEGA transmitter station in Australia. He described results of an extensive ship-borne study. The occurrence of cycle jumps occurs in paths to the north and northwest of the Australia station. No cause for this seems to be known. Peter Morris (TASC, Inc., US) gave the paper by Richard Barr of New Zealand about OMEGA navigation near the Antarctic Glacial Ice Sheet. Kelly gave a paper in "Long Wave Propagation Studies and Coverage Maps" in which he described NRL's methodology for producing coverage maps for required time availability. Morris gave a paper on "OMEGA System Availability Measures" in which the impact of system transmitter outages could be portrayed in a realistic way. Vern Hildebrand (SRS Technologies, San Diego, California) described preliminary findings about the usefulness of OMEGA in the South Pacific. His indications are that there is a greater area of unstable (modal) signal than is theoretically expected. E. Swanson (US Naval Ocean Systems Center [NOSC], San Diego) described the results of C. Kugel (NOSC) on the possible effects of the Chernobyl disaster on OMEGA in the Pacific. In general, an increase in VLF noise was found at numerous Pacific monitor sites during a particular week during which the Chernobyl nuclear disaster and a very severe Pacific typhoon were occurring. The feeling of the meeting is that the typhoon is the more likely source of the increased noise than the Chernobyl disaster. Ian Birch (RAE, Farnsborough, UK) claimed that there was little or no effect on OMEGA in the Atlantic area by the disaster.

Proceedings of this meeting and information about OMEGA may be obtained from the International Omega Association, Inc., PO Box 2324, Arlington, Virginia 22202-0324.

Telecommunications

Traveler: Dr. J.F. Blackburn, London representative of the US Commerce Department (Dr. Blackburn may be addressed at ONREUR).

Dr. Blackburn attended the Second Conference and Exhibition of European Telecommunications, organized by the Spanish Ministry of Transport, Tourism, and Communications with the support of the European Community (EC). Blackburn states that the series (this conference being the second in the series) shows that the Spanish authorities are well aware of the importance of telecommunications in the development of Spain for the European Community, and that it is well recognized throughout the EC that high-quality telecommunications services are essential for the success of the Community internal market planned for 1992. Speakers came from the European Commission and most EC member companies.

Blackburn's report of this meeting consists of the verbatim speeches of many of the presenters and of summaries of others.